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Costs of Particulate Matter Controls for Nonfossil Fuel Fired Boilers

Radian Corp.
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Costs of Particulate Matter Controls for Nonfossil Fuel Fired Boilers

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This report is a resource document for the development of Federal standards of performance for control of particulate matter from new nonfossil fuel-fired boilers ranging in size from 30 to 400 million Btu/hour heat input. Capital and annualized costs for a variety of alternative emission control systems are given for wood, bark, solid waste (refuse), and bagasse fired boilers.

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1.0 INTRODUCTION

The purpose of this report is to provide supporting cost information for a potential new source performance standard for nonfossil fuel-fired boilers. This report presents a cost analysis of particulate matter (PM) control technologies applied to wood-, bagasse-, and solid waste-fired boilers. The emphasis is to quantify the individual boiler cost impacts associated with various control strategies. Also shown are the data used to calculate these costs. Both uncontrolled and controlled boiler costs are examined. By comparing the costs of different control technologies, the incremental cost impact of these technologies can be assessed.

1.1 ORGANIZATION

Chapter 2 presents the methodology used to develop model boiler costs. Chapter 2 includes the data and references used to develop the design specifications for the boilers and PM control systems, and to calculate the costs of the specified systems. The cost results obtained using the cost methodology in Chapter 2 are shown in Chapter 3. Chapter 4 presents some individual cases that are not covered by the model boiler categories.

Appendices are included for reference. Appendix A provides the detailed line-by-line costs for each of the boiler cases examined. Appendix B gives escalation factors for updating costs. All costs in this report are in mid-1978 dollars.

1.2 BOILER CASES EXAMINED

The first step in determining the cost cases to be examined is to specify the standard boilers. A standard boiler represents an uncontrolled boiler of a specific size and type. Standard boilers are selected to represent the new NFFB population. Factors used in their selection include fuels, firing methods, and boiler distribution by capacity. A summary of the standard boilers selected for evaluation is presented in Table 1-1. The rationale used to select the boiler fuels and capacities are discussed in

TABLE 1-1. STANDARD BOILERS SELECTED FOR EVALUATION

Boiler Type	Fuel[a]	Heat Input MW	(10^6 Btu/hr)
Spreader Stoker	Wood	8.8	(30)
Spreader Stoker	Wood	22	(75)
Spreader Stoker	Wood	44	(150)
Spreader Stoker	Wood	117	(400)
Overfeed Stoker	MSW	44	(150)
Overfeed Stoker	MSW	117	(400)
Spreader Stoker	Bagasse	58.6	(200)

[a] Wood - hog fuel (wood/bark mixture).
MSW - municipal solid waste.

Section 1.2.1. The selection of the boiler firing method is discussed in Section 1.2.2. After standard uncontrolled boiler cases have been selected, the control methods and emission levels are selected and combined with the standard boilers. The combined standard boiler and emission control system is called a "model" boiler. The selection of control methods and emission levels is discussed in Section 1.3.

1.2.1 Selection Rationale

The boiler capacities, firing methods, and fuels reflected in the standard boilers represent current and future designs based on the NFFB population data. The principal NFFB fuels are wood and bark waste, solid waste including municipal solid waste (MSW) and refuse derived fuel (RDF), and bagasse. Boilers are selected to represent each of these basic fuel types. Representative capacities for each fuel type are then selected within the range of expected capacities for the new NFFB population. Whenever practical, boiler capacities for the nonfossil fuel fired boilers were selected to be the same as those selected in the cost report for fossil fuel fired boilers.[1] These selection criteria were applied to facilitate direct comparisons between the fossil fuel fired boiler and nonfossil fuel fired boiler studies, and to allow comparison of the economic, environmental, and energy impacts resulting from alternative control technologies.

Capacities of NFFBs range from less than 2.9 MW (10 x 10^6 Btu/hr) to greater than 117 MW (400 x 10^6 Btu/hr) of thermal input. However, the bulk of NFFB capacity consists of watertube boilers larger than 7.3 MW (25 x 10^6 Btu/hr). Many boilers at the lower end of the capacity range are used for space heating, whereas the boilers at the upper end of the capacity range are generally used to produce process steam, to drive turbines, and in some cases, to generate electricity. In Table 1-2, the NFFB capacity range is segmented into four size categories with appropriate standard boilers chosen to represent each capacity interval.

The bulk of the wood-fired boiler capacity sold consists of watertube boilers larger than 7.3 MW (25 x 10^6 Btu/hr) thermal input. Smaller boilers are generally of the firetube design and are commonly used in the furniture industry. Emission rates, while variable, are similar across the entire capacity range.

TABLE 1-2. REPRESENTATIVE STANDARD BOILER CAPACITIES

	Capacity Range - Thermal Input			
Fuel[a]	7.3-14.7 MW ($25-50 \times 10^6$ Btu/hr)	14.7-29.3 MW ($50-100 \times 10^6$ Btu/hr)	29.3-73.3 MW ($100-250 \times 10^6$ Btu/hr)	>73.3 MW ($>250 \times 10^6$ Btu/hr)
Wood	8.8 MW (30×10^6 Btu/hr)	22.0 MW (75×10^6 Btu/hr)	44.0 MW (150×10^6 Btu/hr)	117 MW (400×10^6 Btu/hr)
MSW			44.0 MW (150×10^6 Btu/hr)	117 MW (400×10^6 Btu/hr)
Bagasse			58.6 MW (200×10^6 Btu/hr)	

[a] Wood - hog fuel (wood/bark mixture).
MSW - municipal solid waste.

Four wood-fired boiler sizes of similar design were selected to show the cost impacts on various size boilers. These sizes are 8.8, 22, 44, and 117 MW (30, 75, 150, and 400 x 10^6 Btu/hr) thermal input. The fuel selected for these standard boiler sizes is a hog fuel representative of wood fuels fired in most wood-fired boilers in the United States. Other wood fuels, such as high ash bark (HAB), have similar costs of control to hog fuel at similar emission levels.[2] Costs for boilers firing mixtures of wood and fossil fuels are discussed in Chapter 4.

Two MSW-fired boiler sizes were selected for evaluation, 44 and 117 MW (150 and 400 x 10^6 Btu/hr) thermal input. These capacities are expected to cover the range of sizes for most new large mass burn MSW-fired boilers. The other type of solid waste-fired boiler, the "controlled" or "starved" air boiler, is only produced in the smaller size ranges and is not included in this report.

RDF may be fired alone or cofired with coal. However, the most recent new boilers built to fire RDF have been designed to fire RDF alone. Little emission data are currently available for RDF-fired boilers so no standard boiler can be evaluated for this fuel. However, the estimated costs for RDF-fired boiler PM emission controls are discussed in Chapter 4.

One standard boiler capacity, 58.6 MW (200 x 10^6 Btu/hr), representing bagasse-fired boilers was selected. Most bagasse-fired boilers sold had a thermal input capacity of about this size or larger. A smaller bagasse-fired boiler was not included in the analysis because few if any smaller boilers are anticipated to be built. A larger boiler was not evaluated since economies of scale would be expected in both boiler and emission control costs.

1.2.2 Characterization of Standard Boilers

The firing mechanisms for the majority of new wood-fired boilers are similar across the capacity range. These units are primarily spreader or overfeed stokers with the major differences being in the type of grate selected.[3] Some other firing methods used at times to fire wood include Dutch ovens, fuel cells, and fluidized beds. However, Dutch ovens have been phased out for new construction due to high costs, low efficiencies, and inability to follow load swings. Particulate emission rates from the other firing mechanisms are usually less than from spreader stokers. Because of the prevalence of spreader stokers as a firing mechanism for wood-fired boilers all of the wood-fired standard boilers were selected to be spreader stokers.

The firing method for MSW-fired boilers is the overfeed stoker design. This design is the only firing method used for large mass burn MSW-fired boilers.

Bagasse-fired boilers use spreader stokers, fuel cells, and horseshoes as firing methods. Horseshoes and fuel cells are pile burning designs similar to the Dutch oven used to fire wood. They differ in the shape of the furnace area but in other respects are similar in design and operation. The basic design of the bagasse-fired spreader stoker is the same as that of the wood-fired spreader stoker. Most new bagasse-fired boilers are expected to use spreader stokers so this design was selected for the bagasse-fired standard boiler.[4]

1.3 SELECTION OF EMISSION CONTROL SYSTEMS AND EMISSION LIMITS

Costs for different control levels and types of emission controls are calculated for each standard boiler case. This allows the cost impacts for different control levels and control technologies to be compared. The control technologies that were selected were the technologies that new NFFBs would be expected to use in the absence of an NSPS, and the technologies which form the basis of the NSPS. Each combination of a standard boiler, emission level, and control technology is given a "model" boiler designation. Table 1-3 shows the emission levels and control technologies selected for model boiler cost evaluations.

TABLE 1-3. MODEL BOILERS[a]

Model Boiler Number	Fuel	Heat Input Capacity MW (10^6 Btu/hr)	Uncontrolled PM Emission Level ng/J (lb/10^6 Btu)	Controlled PM Emission Level ng/J (lb/10^6 Btu)	Control[b] Device(s)
WOOD-30-MC (0.60)	Wood	8.8 (30)	2100 (4.88)	258 (0.6)	MC
WOOD-30-DM (0.40)	Wood	8.8 (30)	2100 (4.88)	172 (0.4)	DM
WOOD-30-MC/WS (0.30)	Wood	8.8 (30)	2100 (4.88)	129 (0.3)	MC, WS
WOOD-30-MC/WS (0.15)	Wood	8.8 (30)	2100 (4.88)	64.5 (0.15)	MC, WS
WOOD-30-MC/WS (0.05)	Wood	8.8 (30)	2100 (4.88)	21.5 (0.05)	MC, WS
WOOD-75-MC (0.60)	Wood	22 (75)	2100 (4.88)	258 (0.6)	MC
WOOD-75-MC (0.40)	Wood	22 (75)	2100 (4.88)	172 (0.4)	DM
WOOD-75-MC/WS (0.30)	Wood	22 (75)	2100 (4.88)	129 (0.3)	MC, WS
WOOD-75-MC/WS (0.15)	Wood	22 (75)	2100 (4.88)	64.5 (0.15)	MC, WS
WOOD-75-MC/WS (0.05)	Wood	22 (75)	2100 (4.88)	21.5 (0.05)	MC, WS
WOOD-150-MC (0.60)	Wood	44 (150)	2100 (4.88)	258 (0.6)	MC
WOOD-150-DM (0.40)	Wood	44 (150)	2100 (4.88)	172 (0.4)	DM
WOOD-150-MC/WS (0.30)	Wood	44 (150)	2100 (4.88)	129 (0.3)	MC, WS
WOOD-150-MC/WS (0.15)	Wood	44 (150)	2100 (4.88)	64.5 (0.15)	MC, WS
WOOD-150-MC/WS (0.05)	Wood	44 (150)	2100 (4.88)	21.5 (0.05)	MC, WS
WOOD-400-MC (0.60)	Wood	117 (400)	2100 (4.88)	258 (0.6)	MC
WOOD-400-DM (0.40)	Wood	117 (400)	2100 (4.88)	172 (0.4)	DM
WOOD-400-MC/WS (0.30)	Wood	117 (400)	2100 (4.88)	129 (0.3)	MC, WS
WOOD-400-MC/WS (0.15)	Wood	117 (400)	2100 (4.88)	64.5 (0.15)	MC, WS
WOOD-400-MC/WS (0.05)	Wood	117 (400)	2100 (4.88)	21.5 (0.05)	MC, WS
MSW-150-ESP (0.17)	MSW	44 (150)	1440 (3.36)	73.1 (0.17)	ESP
MSW-150-ESP (0.10)	MSW	44 (150)	1440 (3.36)	43.0 (0.10)	ESP
MSW-150-ESP (0.05)	MSW	44 (150)	1440 (3.36)	21.5 (0.05)	ESP
MSW-400-ESP (0.17)	MSW	117 (400)	1440 (3.36)	73.1 (0.17)	ESP
MSW-400-ESP (0.10)	MSW	117 (400)	1440 (3.36)	43.0 (0.10)	ESP
MSW-400-ESP (0.05)	MSW	117 (400)	1440 (3.36)	21.5 (0.05)	ESP
BAG-200-MC (0.62)	Bagasse	58.6(200)	2170 (5.05)	267 (0.62)	MC
BAG-200-MC (0.30)	Bagasse	58.6(200)	2170 (5.05)	129 (0.3)	WS
BAG-200-MC (0.20)	Bagasse	58.6(200)	2170 (5.05)	86 (0.2)	WS

[a] Wood - hog fuel (wood/bark mixture).
MSW - municipal solid waste.

[b] MC - mechanical collector.
DM - dual mechanical collector.
WS - wet scrubber.
ESP - electrostatic precipitator.
Control systems separated by a comma mean that both are used at the same time, not that either may be used independently. Differences in emission levels for similar control systems are based on differences in control system design (see Table 2.1-4).

1.4 REFERENCES

1. Bowen, M.L. and M.S. Jennings. (Radian Corporation.) Costs of Sulfur Dioxide, Particulate Matter, and Nitrogen Oxide Controls on Fossil Fuel Fired Industrial Boilers. (Prepared for U.S. Environmental Protection Agency.) Research Triangle Park, N.C. Publication No. EPA-450/3-82-021. May 1982. p. 2-3.

2. U.S. Environmental Protection Agency. Nonfossil Fuel Fired Industrial Boilers - Background Information. Research Triangle Park, N.C. EPA Publication No. 450/3-82-007. March 1982. pp. 8-22 to 8-38.

3. Schwleger, B. Power from Wood. Power. 124:S.22 - S.23. February 1980.

4. Memo from Barnett, K., Radian Corporation, to file. January 27, 1982. 22 p. Projections of new nonfossil fuel fired boilers (NFFBs).

2.0 METHODOLOGY FOR CALCULATING UNCONTROLLED BOILER AND PM CONTROL SYSTEM COSTS

This chapter presents the bases used to calculate capital and annualized costs for uncontrolled standard boilers and the particulate matter (PM) emission control systems shown in Section 1.3. Section 2.1 discusses how capital costs were calculated, including boiler and control equipment design specifications and the sources for the cost data. Section 2.2 presents the bases used to calculate annualized costs.

2.1 CAPITAL COSTS

This section presents the information used to develop capital costs for boilers and PM control systems.

2.1.1 Capital Cost Components

The capital cost is the total investment required to supply a complete boiler/emission control system. Components of the capital costs, itemized in Table 2.1-1, include total direct and indirect investment costs, contingencies, land, and working capital.

The equipment costs are the basis of the other capital cost components listed in Table 2.1-1. The cost of equipment installation, for example, is estimated as a fraction of the equipment cost. Other cost components such as engineering are then estimated as fractions of the sum of the equipment and installation costs.

The boiler capital costs include the following boiler equipment items:

- fuel handling and storage systems;
- feedwater and condensate treatment systems;
- boiler and auxiliaries (feed pumps, chemical feed system, soot blowers, instrumentation, and FD and ID fans); and
- bottom ash disposal systems.

Equipment included in the capital costs attributed to the emission control system include:

- control equipment and auxiliaries;

TABLE 2.1-1. CAPITAL COST COMPONENTS[1,2]

---

(1) DIRECT INVESTMENT COSTS

Equipment
Installation

TOTAL DIRECT INVESTMENT COSTS (TDI)

(2) INDIRECT INVESTMENT COSTS

Engineering[a]
Construction and Field Expense[b]
Construction Fees[b]
Start Up Costs[c]
Performance Tests[d]

TOTAL INDIRECT INVESTMENT COSTS (TII)

(3) CONTINGENCIES[e]

TOTAL TURNKEY COSTS (TTC)[f]

(4) LAND[g]

(5) WORKING CAPITAL[h]

TOTAL CAPITAL COSTS (Total Turnkey Costs + Land + Working Capital)

---

[a] Estimated as 10% of Total Direct Investment Costs (TDI) for boiler and PM control systems.

[b] Estimated as 10% of TDI.

[c] Estimated as 2% of TDI.

[d] Estimated as greater of 1% of TDI or $3,000.

[e] Estimated as 20% of the sum of TDI and TII.

[f] Sum of TDI, TII, and Contingencies.

[g] Estimated as: $1,000 for boilers with heat input capacities <22 MW (75 x 10^6 Btu/hr); $2,000 for boilers with heat input capacities >22 MW (75 x 10^6 Btu/hr); 0.084% of TTC for emission control systems.

[h] Estimated as 25% of Total Direct Operating Costs.

- ducting (from the boiler system to the emission control system and stack);
- fans (increased fan capacity for overcoming control system pressure drop);
- solids separation systems; and
- fly ash disposal systems.

In some model boilers, the bottom ash disposal system is combined with the fly ash disposal system. In allocating the capital cost of the ash disposal system, only the incremental cost of the combined system over the cost of a bottom ash disposal system is allocated to the emission control capital cost.

The control system capital costs were developed in terms of mid-1978 dollars and are generally accurate to ±30%. Boiler costs were developed without detailed evaluation of equipment costs and are expected to be less accurate than the control system costs.

2.1.2 Standard Boiler Specifications

The specifications for the standard boilers provide the basis for calculating the costs of uncontrolled boilers. The primary specifications used in this analysis are:

- Fuel type and quality
- Design capacity and load factor
- Flue gas characteristics

Each of these areas is discussed below. Table 2.1-2 presents design specifications for the standard boilers.

2.1.2.1 Fuels. The fuel specifications have been chosen to represent currently available choices for nonfossil fuels and are presented in Table 2.1-3. The fuel characteristics, including heating value and chemical analysis, are specified to determine the combustion-related characteristics of the standard boilers.

All of the standard boilers firing wood use a wood fuel analysis representative of a hog fuel,[3] which is a mixture of wood and bark and is representative of wood fuels fired in most wood-fired boilers in the United

TABLE 2.1-2. UNCONTROLLED MODEL BOILER DESIGN SPECIFICATIONS

Model Boiler Number	WOOD-30	WOOD-75	WOOD-150	WOOD-400
Thermal input, MW (10^6 Btu/hr)	8.8 (30)	22.0 (75)	44.0 (150)	117 (400)
Fuel[a]	Wood	Wood	Wood	Wood
Fuel rate, kg/s (ton/hr)	0.829 (3.29)	2.07 (8.22)	4.15 (16.4)	11.1 (43.9)
Analysis				
% sulfur	0.02	0.02	0.02	0.02
% ash	1.00	1.00	1.00	1.00
Heating value, kJ/kg (Btu/lb)	10,600 (4,560)	10,600 (4,560)	10,600 (4,560)	10,600 (4,560)
Excess air, %	50	50	50	50
Flue gas flow rate, m^3/s (acfm)	6.94(14,700)	17.3(36,700)	34.7(73,500)	92.5 (196,000)
Flue gas temperature, K (°F)	478 (400)	478 (400)	478 (400)	478 (400)
Load factor, %	60	60	60	60
Flue gas constituents,[b] kg/hr (lb/hr)				
Fly ash (before mechanical collector)[c]	66.2 (146)	166 (366)	332 (732)	885 (1950)
(after mechanical collector)[f]	13.3 (29.3)	33.2 (73.2)	66.4 (146)	177 (390)
SO_2	-	-	-	-
NO_x	3.40 (7.50)	8.53 (18.8)	17.0 (37.5)	45.3 (100)
Ash from sand classifier,[g] kg/hr (lb/hr)	29.2 (64.4)	73.0 (161)	146 (322)	390 (859)
Bottom ash, kg/hr (lb/hr)	20.1 (44.4)[h]	50.3 (111)[h]	101 (222)[h]	269 (592)[h]
Boiler Output, MW (10^6 Btu/hr)				
Steam	5.7 (19.5)	14.3 (48.7)	28.6 (97.5)	76.1 (260)
Losses	3.1 (10.5)	7.7 (26.3)	15.4 (52.5)	41.0 (140)
Efficiency, %	65	65	65	65
Steam quality[d]				
Pressure, kPa (psig)	1,720 (250)	1,720 (250)	1,720 (250)	5,170 (750)
Temperature, K (°F)	481 (406)	481 (406)	481 (406)	672 (750)
Steam production,[e] kg/hr (lb/hr)	8,890 (19,600)	22,200 (49,000)	44,500 (98,200)	101,000 (223,000)

See footnotes at end of table.

TABLE 2.1-2. (CONTINUED)

Model Boiler Number	MSW-150	MSW-400	BAG-200
Thermal input, MW (10^6 Btu/hr)	44.0 (150)	117 (400)	58.6 (200)
Fuel[a]	MSW	MSW	Bagasse
Fuel rate, kg/s (ton/hr)	3.88 (15.4)	10.3 (41.0)	6.43 (25.5)
Analysis			
% sulfur	0.12	0.12	Trace
% ash	22.38	22.38	1.10
Heating value, kJ/kg (Btu/lb)	11,340 (4,875)	11,340 (4,875)	9,116 (3,920)
Excess air, %	100	100	50
Flue gas flow rate, m^3/s (acfm)	41.8 (88,500)	111 (236,000)	47.7 (101,000)
Flue gas temperature, °K (°F)	478 (400)	478 (400)	478 (400)
Load factor, %	60	60	45
Flue gas constituents,[b] kg/hr (lb/hr)			
Fly ash (before mechanical collector)[c]	229 (504)	608 (1,340)	458 (1,010)
(after mechanical collector)[f]	-	-	-
SO_2	33.5 (73.8)	89.3 (197)	-
NO_x	21.0 (46.2)	56.0 (123)	18.1 (40.0)
Ash from sand classifier,[g] kg/hr (lb/hr)	-	-	-
Bottom ash, kg/hr (lb/hr)	3,490 (7,690)	9,310 (20,500)	145 (319)
Boiler Output, MW (10^6 Btu/hr)			
Steam	30.8 (105)	81.9 (280)	35.2 (120)
Losses	13.2 (45)	35.1 (120)	23.4 (80)
Efficiency, %	70	70	60
Steam quality			
Pressure,[d] kPa (psig)	3,100 (450)	5,170 (750)	1,720 (250)
Temperature, °K (°F)	589 (600)	672 (750)	533 (500)
Steam production,[e] kg/hr (lb/hr)	43,600 (96,000)	109,000 (241,000)	51,700 (114,000)

See footnotes at end of table.

FOOTNOTES TO TABLE 2.1-2:

[a] Wood - hog fuel (wood/bark mixture)
MSW - municipal solid waste

[b] Uncontrolled emissions.

[c] Fly ash before mechanical collector means uncontrolled emissions prior to any control device whether a mechanical collector is used or not.

[d] Guage pressure.

[e] Assuming a saturated condensate return at 10 psig.

[f] Fly ash after the mechanical collector is shown only for cases where fly ash reinjection is used. The value shown represents a mechanical collector used as a precleaner prior to another control device. For model boilers WOOD-30-MC (0.60), WOOD-75-MC (0.60), WOOD-150-MC (0.60), and WOOD-400-MC (0.60), where the mechanical collector is the final control device, this value would be the mass equivalent of an emission level of 258 ng/J (0.6 lb/10^6 Btu).

[g] Sand classifiers are only used with systems employing fly ash reinjection (model boilers WOOD-30 through WOOD-400. The value shown represents the differences in the amount of fly ash collected by the mechanical collector and the amount of fly ash reinjected into the boiler furnace.

[h] These values are for cases where the mechanical collector is used as a precleaner prior to another control device. Where the mechanical collector is the final control device, these values would be 34.3, 85.7, 171, and 458 kg/hr (75.7, 189, 378, and 1009 lb/hr) for model boilers WOOD-30-MC(0.60), WOOD-75-MC (0.60), WOOD-150-MC (0.60), and WOOD-400-MC (0.60) respectively.

States. The fuel moisture, sulfur, and nitrogen contents were selected as representative values based on other literature data[4] and on fuel analyses from emission test reports.

The MSW composition was taken from a performance test conducted on boilers at an operating facility.[5] The analysis compares closely with reported "typical" compositions for MSW[6] except that the heating value of the selected waste is somewhat higher. However, the heating value of MSW in the United States has been increasing with time, and the heating value of the selected waste falls well within the range of values predicted by several studies for the 1985 - 1990 time frame.[7]

The bagasse composition was based on an average dry composition reported in the "Cane Sugar Handbook".[8] Sulfur and nitrogen concentrations were based on values reported in various other sources. Fuel moisture was set at an intermediate level based on values reported in "The Gilmore Sugar Manual".[9]

2.1.2.2 Boiler capacities and load factors. The capacities of the standard boilers selected are based on the maximum heat input to the boiler. The heat input together with the heating value of the fuel determines the fuel firing rate. To quantify the steam output, the thermal efficiency and steam quality of the boiler must be specified. The thermal efficiency of the boiler is the measure of the percentage of heat input which is transferred to the steam cycle and is a function of the fuel properties, firing method, flue gas characteristics, and boiler heat losses. Thermal efficiencies shown in Table 2.1-2 are generally based on values reported in the literature for wood,[10] MSW,[11,12] and bagasse-fired[13] boilers.

The quality of the steam is specified in terms of temperature and pressure. The steam quality varies with the intended steam use. The steam temperatures and pressures specified for the standard boilers are those commonly found in various applications for the selected boiler capacities. Steam qualities were selected based on watertube boiler sales data[14] for wood and bagasse-fired boilers, and various literature references.[15,16]

The capacities of the standard boilers represent maximum firing rates. Boilers, however, seldom operate at maximum capacity year-round. To analyze impacts on an annual operating basis, an appropriate measure of actual boiler usage must be selected. The load factor (or capacity utilization factor) is the actual annual fuel consumption as a percentage of the potential annual fuel consumption at maximum firing rate. Load factors for industrial boilers are estimated to range from 30 to 80 percent.[17] Load factors for MSW resource recovery plants installed by 1990 are forecasted to average 60-80 percent.[18]

Low load factors generally represent "nonprocess" boilers or boilers used in seasonal industries, such as bagasse-fired boilers. High load factors generally represent process or utility boilers whose output is tied directly to plant production. Load factors can vary considerably from plant to plant and from industry to industry and are influenced by such items as the economic climate of the country, the availability of nonfossil fuels, the reliability of the boiler and fuel feeding equipment, and decisions to buy oversized boilers to allow for plant expansions. Load factors for the standard boilers were generally set at 60 percent for each boiler and fuel combination. Bagasse-fired boilers were assigned a lower load factor of 45 percent due to the seasonal nature of the industry.

2.1.2.3 Flue gas characteristics. Temperature, composition, and volumetric flow rate are the main flue gas characteristics upon which the design of emission control systems are based. These characteristics are mainly affected by fuel composition and boiler excess air. Fuel analyses are presented in Table 2.1-3. A representative excess air value was selected for each standard boiler and is included in Table 2.1-2. The pollutant concentrations in the flue gas are calculated based on the excess air rate, the chemical composition of the fuel, and the pollutant emission factors developed in Chapter 3 of "Nonfossil Fuel Fired Industrial Boilers - Background Information" for each standard boiler.[19]

2.1.3 PM Control System Design Specifications

Emissions control system design specifications are detailed in Table 2.1-4. These specifications are based on emission test data and design data from existing NFFB facilities.

TABLE 2.1-3. ULTIMATE ANALYSES OF THE FUELS SELECTED FOR MODEL BOILERS

Composition, % by weight	Fuel[a]		
	Wood	MSW[b]	Bagasse
Moisture	50.0	27.14	52.00
Carbon	26.95	26.73	22.60
Hydrogen	2.85	3.60	3.10
Nitrogen	0.08	0.17	0.10
Oxygen	19.10	19.74	21.10
Sulfur	0.02	0.12	Trace
Ash	1.00	22.38	1.10
Gross Heating Value kJ/kg (Btu/lb)	10,600 (4,560)	11,340 (4,875)	9,116 (3,920)

[a] Wood - hog fuel (wood/bark mixture); MSW - municipal solid waste.

[b] Composition does not total 100 percent due to the presence of chlorine which is not shown here.

TABLE 2.1-4. EMISSION CONTROL SYSTEM DESIGN SPECIFICATIONS

Control System	Item	Specification
Multiple cyclone	Material of construction	Carbon steel
	Tube diameter	23 cm (9 in.)
	Pressure drop	750 Pa (3 in. w.c.)
	Design PM removal efficiency	Model boilers WOOD-MC (0.60) and BAG-200-MC (0.62): 88% WOOD-DM (0.40) (upstream), WOOD-MC/WS (0.30), WOOD-MC/WS (0.15), and WOOD-MC/WS (0.05): 80% WOOD-DM (0.40) (downstream): 60%
Wet Scrubbers	Material of construction	FRP-lined carbon steel
	Scrubber type	Model boilers WOOD-MC/WS (0.30): impingement WOOD-MC/WS (0.15), WOOD-MC/WS (0.05), BAG-200-WS (0.30), and BAG-200-WS (0.20): variable throat venturi
	Liquid-to-gas ratio (L/G)	Impingement scrubbers: 0.4 dm^3 liquid/m^3 gas (3 gal/1000 acf) Venturi scrubbers: 0.4 dm^3 liquid/m^3 gas (10 gal/1000 acf)
	Liquid discharge pressure	170 kPa (10 psig)
	Liquid pumping height	6 m (20 ft.)
	Length of piping	30 m (100 ft.)
	Sludge handling equipment/ characteristics	Clarifier; sludge comprises 30% solids (except for BAG-200-WS (0.30) and BAG-200-WS (0.20) where no clarifier is used)

TABLE 2.1-4. (CONTINUED)

Control System	Item	Specification
Wet Scrubbers	Pressure drop (gas-phase) and design PM removal efficiency	Model Boilers WOOD-MC/WS (0.30); 1kPa (4 in. w.c.); 69% WOOD-MC/WS (0.15); 2.2kPa (9 in. w.c.); 84% WOOD-MC/WS (0.05); 5kPa (20 in. w.c.); 95% BAG-200-WS (0.30); 1.5kPa (6 in. w.c.); 94% BAG-200-WS (0.20); 2.5 kPa (10 in. w.c.); 96%
	Venturi scrubber separator pressure drop	750 Pa (3 in. w.c.)
	Mist eliminator pressure drop	250-500 Pa (1-2 in. w.c.) (Mist eliminators are installed only on scrubbers with gas-phase pressure drops exceeding 1.2 kPa or 5 in. w.c.)
Electrostatic Precipitator	Material of construction	Carbon steel (insulated)
	Design specific collection area	Model boilers MSW-ESP (0.17): 24 $m^2/(m^3/s)$ (160 ft^2/1000 acfm); 94.9% MSW-ESP (0.10): 47 $m^2/(m^3/s)$ (240 ft^2/1000 acfm); 97.0% MSW-ESP (0.05): 93 $m^2/(m^3/s)$ (410 ft^2/1000 acfm); 98.5%
	Pressure drop	250 Pa (1 in. w.c.)
	Power demand (average)	Model boilers MSW-150 and MSW-400; 32 W/m^2 plate area (3 W/ft^2)
Overall System	Pressure drop	250-750 Pa (1-3 in. w.c.) plus pressure drops from individual control equipment
	Duct features	Main duct length: 20-30 m (60-100 ft) Expansion joints for duct connecting two pieces of control equipment Elbows Transition ducting for ESPs

2.1.4 Calculation of Capital Costs of Uncontrolled Model Boilers

Uncontrolled boiler costs were based on owner/vendor data and previously estimated costs for fossil fuel fired boilers.[20] This study did not attempt to develop boiler system costs by separately considering the costs of individual boiler subsystems. Considering the boiler subsystems separately would have required a more detailed analysis and design of boiler systems than possible within the scope of this study.

The costs for uncontrolled boilers were developed as total turnkey costs (TTC). Land and working capital costs were calculated using the factors shown in Table 2.1-1. The generalized equation used to estimate TTC was:

$$\text{total turnkey costs } (\$1000) = ax^b$$

where x is the boiler heat input capacity in million Btu per hour.

The capacity exponent "b" was assumed to be 0.77 based on literature data[21] and costs developed for coal-fired boilers.[22] Cost data from boiler owners, vendors, or literature was used to estimate the value of "a" for each fuel. The resulting correlations for each fuel type are shown in Table 2.1-5.

2.1.5 Calculation of capital costs of PM control systems

As discussed in Section 2.1.1, equipment costs are the basis of the other capital cost components. Therefore, this section will mainly discuss equipment costs. The factors used to estimate installation costs from equipment costs are shown in Table 2.1-6. Factors used to estimate the remaining components of the capital cost are shown in Table 2.1-1.

2.1.5.1 Multiple cyclone. Costs for 9" tube diameter multiple cyclones are based on data from a vendor. These costs are presented in Table 2.1-7.

2.1.5.2 Electrostatic precipitator (ESP). ESP costs are estimated from cost algorithms presented in PEDCO's "Capital and Operating Costs of Particulate Controls on Coal and Oil-fired Industrial Boilers.[24] These algorithms estimate the ESP equipment cost (in $\$/ft^2$ of collecting surface area) as a function of the total ESP collection area. The total ESP collection area (TPA) is simply estimated as:

TABLE 2.1.5. CAPITAL COST CORRELATION FOR UNCONTROLLED NONFOSSIL FUEL FIRED BOILERS

Fuel	Cost Correlation[a]
Wood	$TTC = 127.3x^{0.77}$
Bagasse	$TTC = 93.385x^{0.77}$
Municipal Solid Waste	$TTC = 343.82x^{0.77}$

[a] TTC - total turnkey cost ($1000).
x - boiler heat input capacity (10^6 Btu/hr).

TABLE 2.1-6. EQUIPMENT INSTALLATION COST FACTORS

Equipment Item	Installation Cost Factor[a]	Source
I. Emission Control Equipment		
A. Multiple cyclone	0.78	Refs. 26, 29
B. Electrostatic precipitator	1.0	Ref. 24
C. Wet scrubber	0.68	Ref. 26
II. Scrubber Auxiliaries		
A. Circulation pumps	1.49	Ref. 27
B. Piping[b]	0.0	Ref. 27
C. Circulation tank	0.93	Ref. 29
III. Fan	1.18	Ref. 29
IV. Solids Separation	1.5	Ref. 30
V. Ducting	1.6	Ref. 24
VI. Ash removal		
A. Dumpster	0.33	Ref. 24
B. Pneumatic conveying system/silo	1.0	Ref. 24
VII. Screen for Sand Classification	1.34	Ref. 24

[a] The installation cost is equal to the ratio of

$$\frac{\text{Cost of Equipment Installation}}{\text{Equipment Cost}}$$

Items included in the installation cost are the following:

(1) freight and taxes
(2) foundations and supports
(3) erection and handling
(4) electrical
(5) piping
(6) insulation
(7) painting
(8) building (boiler)

[b] Materials cost for piping includes installation.

TABLE 2.1-7. MULTIPLE CYCLONE EQUIPMENT COSTS[24]

Flow Rate, acfm	Multiclone Equipment Costs Mid-1980 $
14,000	9,600
35,000	20,300
69,000	36,700
97,000	48,000
187,000	96,000

$$\text{TPA (ft}^2\text{) = Gas Flow (acfm)} \times \text{Design SCA (ft}^2\text{/1000 acfm)} \times 1.1$$

where 1.1 is a design contingency factor. The ESP equipment cost (in $/ft^2) is estimated with one of two equations:

$$\text{for TPA} < 28{,}000 \text{ ft}^2\text{, cost (\$/ft}^2\text{)} = 24.57 - 5.62 \left(\frac{\text{TPA}}{10^4}\right)$$

$$\text{for TPA} \geq 28{,}000 \text{ ft}^2\text{, cost (\$/ft}^2\text{)} = 9.65 - 2.54 \left(\frac{\text{TPA}}{10^5}\right)$$

2.1.5.3 Wet scrubber and auxiliaries. Equipment costs for impingement scrubbers are based on vendor data and are estimated as a function of the saturated gas flow leaving the scrubber.[25] The cost correlation is:

$$\text{Cost (\$1000)} = 3.15 \times \text{(Saturated Gas Flow, acfm)}^{0.75}$$

The cost correlation shown applies to impingement scrubbers made of SS 304. Costs for scrubbers featuring different materials of construction are adjusted by the following factors:

- for FRP-lined carbon steel, multiply above cost by 0.5
- for SS 316, multiply above cost by 1.30

Equipment costs for venturi scrubbers are estimated from GARD[26] as a function of the gas flow entering the scrubber, the required design pressure drop, and the material of construction. The use of GARD's cost correlations is described in detail in pages 5-11 through 5-18 of Reference 26, and is not further described here. The GARD costs include the costs of the venturi scrubber, elbow, cyclonic-type separator, pumps, and controls. Costs shown in Chapter 3 assume the use of a manually adjusted variable venturi throat.

Equipment costs for mist eliminators are not considered in this cost analysis because mist eliminators are inexpensive relative to the cost of scrubbers. (Energy costs due to the gas-phase pressure drop of the mist eliminators are included.)

Scrubber auxiliaries include piping, circulation tanks, and circulation pumps. The estimation of the cost of these auxiliaries varies with the type of scrubber used.

Piping costs are estimated for both venturi and impingement scrubbing systems. Piping costs are based on a 100-foot length of stainless steel pipe with an average liquid velocity in the pipe of 10 feet/sec. The cost of the piping is estimated from the required pipe diameter and pipe length, based on data from Process Plant Estimating Evaluation and Control.[27] With the unit piping cost in \$/ft (mid-1970\$) from Reference 27, piping costs, including materials and installation, are then estimated as:

$$\text{Cost } \$ = 100 \text{ ft} \times (\$/\text{ft}) \times 3.22 \times 1.77$$

where 3.22 is a material adjustment factor for stainless steel, and 1.77 is a cost escalation index factor.

Costs for circulation tanks for impingement and venturi wet scrubbers are estimated from Plant Design And Economics For Chemical Engineers[28] as a function of the holding capacity (gal) and the material of the construction. The circulation tank is based on a 5 minute holdup of liquid; holding capacity is simply 5 minutes X L gpm. The equipment cost (January 1967\$) for a tank made of SS 304 is obtained directly from Reference 28. The equipment cost in mid-1978 dollars is 2.05 times the January 1967 cost.

Costs for circulation pumps are estimated from Data and Techniques for Preliminary Capital Cost Estimating.[29] Pump costs are determined from the liquid pumping capacity (gpm) and the pump head (psi). The pumping capacity is determined from the gas flowrate and the liquid-to-gas ratio. The pump head is determined from an energy balance.

The cost of a pump is reported in Reference 29 as a function of a "C/H factor" with units of gpm-psi. The C/H factor is determined by multiplying the pump capacity and head.

For centrifugal pumps used with impingement scrubbers, the cost of the circulation pump and its spare is estimated as:

$$\text{Cost (mid-1978 \$)} = \text{Cost (mid-1968 \$)} \times 1.96 \times 1.93 \times 2$$

where 1.96 is an escalation cost factor, 1.93 is a cost adjustment factor for stainless steel, and 2 is the number of pumps.

As noted previously, the costs for venturi scrubbers include the cost of a circulation pump and its spare. Use of the correlations from Reference 26 estimates the costs of pumps accurately unless the pump construction material differs from the scrubber construction material. For this cost analysis it was assumed that all scrubber auxiliaries are constructed of stainless steel even when the scrubber is made of carbon steel. (Stainless steel is preferred for its superior corrosion resistance.) Thus, the incremental cost of stainless steel pumps needs to be added as a scrubber auxiliary cost when the scrubber construction is lined carbon steel. The incremental cost is estimated as:

$$\text{Cost (mid-1978 \$)} = \text{Cost (mid-1968 \$)} \times 1.96 \times \frac{0.93}{1.15} \times 2$$

where 1.15 is a cost adjustment factor for fiberglass lining and 0.93 is an incremental cost adjustment factor for stainless steel.

2.1.5.4 Fan and auxiliaries. Fan and auxiliaries (inlet damper, motor and starter) costs are determined principally from cost correlations in GARD.[26] The use of GARD's cost correlations is described in detail in Pages 4-57 through 4-70 of Reference 26, and is not discussed further here. Backwardly-curved fans are used in ESP applications and radial-tip fans are used in all other applications.

Fan and inlet damper costs are estimated from the gas flow and the gas pressure drop (corrected with a "sizing factor" from GARD). The costs are corrected with a high-temperature correction factor (1.06) and are escalated to mid-1978 $ by an escalation factor of 1.03.

Motor and starter costs are estimated from the bhp requirements, which are simply calculated from the ghp requirements:

1) bhp = ghp ÷ 0.6 where 0.6 is the fan efficiency.
2) ghp = 1.576×10^{-4} (acfm) (ΔP, in. w.c.).

The motor and starter costs are then obtained directly from GARD correlations (with an escalation factor of 1.03) unless the horsepower requirements exceed the limits of the GARD data. When GARD data for specific applications are unavailable, the cost of the motor and starter are approximated with driver costs reported in Reference 27.

2.1.5.5 Solids separation. Scrubbing systems used for PM removal use clarifiers to produce a sludge comprising 30 percent solids. The costs for solids separation system is estimated from correlations of costs from the Technology Assessment Report for Industrial Boiler Application: Flue Gas Desulfurization.[30] The correlation for solids separation without a vacuum filter, the system used for PM removal is:

$$\text{Cost (\$1000)} = 8.932\ (\text{kg/hr of wet sludge})^{0.351}$$

Note that the sizing and cost of these processing modules depend on the maximum amount of sludge produced. Independently estimated PM solids separation costs may differ.

Bagasse-fired model boilers BAG-200-WS(0.30) and BAG-200-WS(0.20) do not have a solids separation system included in wet scrubber costs. Because these boilers are located at sugar mills, it is possible to combine the wet scrubber waste water with other waste streams. The combined waste water is treated in a central facility or sent to a settling pond.[31] The incremental cost of the addition of the wet scrubber waste water is assumed to be negligible. An installed cost of $5,000 is included for the piping to transport the scrubber waste water for final treatment or disposal.

2.1.5.6 Ducting. Ducting costs are estimated mainly from cost correlations in GARD.[26] Duct costs, in $/ft, are provided in GARD as a function of the duct diameter. The duct costs are simply estimated as the duct length (ft) times the unit duct cost ($/ft). Other ducting component costs, such as costs for elbows, tees, dampers, and expansion joints, are estimated directly from GARD as a function of the duct diameter. All of the costs obtained from GARD are indexed with an escalation factor of 1.03. Duct diameter, which is the key component in estimating duct costs, is calculated as D, in. = 13.54 $Q/V^{0.5}$ where Q is the actual gas flowrate in ft^3/min and V is the gas velocity, assumed to be 3,600 fpm (60 fps).

The costs for ESP transition ducting are determined directly from PEDCo's "Capital and Operating Costs of Particulate Controls on Coal and Oil-Fired Industrial Boilers".[24] As estimated by PEDCo, transition ducting costs vary only with the boiler size (or flue gas flow) and do not vary with ESP size. Transition ducting costs were back calculated from PEDCo's ducting costs by comparing reported ducting costs for comparable baghouse and ESP applications: the difference in costs is assumed to be the cost of the ESP transition ducting. Calculations for transition ducting costs are shown in Table 2.1-8. Costs are not correlated as a function of flue gas flow but instead the estimated transition costs in Table 2.1-8 are used directly. Costs variations due to minor differences in flue gas flows are negligible and are neglected.

2.1.5.7 Ash removal. For model boilers WOOD-30 and WOOD-75 the ash handling systems are simple systems consisting of dumpsters into which the sand classifiers empty directly. The costs for these systems are estimated from Reference 24 as $3000.

For the other model boiler cases costs are based on combined boiler bottom ash/fly ash handling systems. These more "complicated" systems consist of pneumatic piping and valves, an ash storage silo (with affiliated baghouse for dust control), piping and connections from the hoppers to the pneumatic system, and electrical and sequencing controls. The cost for these complicated systems depends on the size of the underhopper piping and the amount of fly ash handled.

The cost correlation for the "complicated" ash handling systems is:

$$\text{Cost (\$1000)} = 38.38\ (\text{lbs/hr of ash removed})^{0.153}$$

TABLE 2.1-8. ESTIMATION OF ESP TRANSITION DUCTING COSTS (MID-1978 $)

Boiler Size 10^6 Btu/hr	PEDCo ESP Duct Costs, $	PEDCo Baghouse Duct Costs, $	Estimated Transition Duct Costs, $
30	27,100	20,100	7,000
	26,600	19,800	6,800
			6,900 (avg)
75	-	-	11,400 (interpolated)
150	64,100	45,000	19,100
	63,000	44,300	18,700
			18,900 (avg)
400	102,400	68,300	34,100
	101,000	67,500	33,500
			33,800

and is based on data from Reference 24. (Note that the cost of ash handling systems is based on the maximum amount of ash removed.) This correlation is used to estimate the costs of bottom ash and combined handling systems. The incremental cost of the combined handling system over the boiler bottom ash system is attributed to the emission control system.

2.1.5.8 Sand classification. Little data are available to design and cost sand classification systems used in fly ash reinjection. Rotary screens appear to be commonly used for sand classification. Because rotary screen costs are not readily available, costs for sand classifiers are approximately estimated here from costs reported in Process Plant Construction Estimating Standards Volume 4[32] for vibrating screens (and costs from GARD[26] for required motors).

Screen costs and horsepower requirements are reported in Reference 31 as a function of the screening area. The required screening area is determined from capacity data (in tons per hour of material passing through one square foot of screen cloth) which is reported in Reference 32 as a function of the screen size and the type of material. Both of these parameters can only be very roughly estimated for wood fly ash reinjection systems since so few data are available.

The estimated screen areas, horsepower requirements, and costs are itemized in Table 2.1-9. Costs from Reference 32 are adjusted with an escalation cost factor 0.88; costs from GARD (Reference 26) are adjusted by a factor of 1.03.

2.1.5.9 Utilities and services. Utilities and services equipment and installation costs are estimated as 6% of all other direct investment costs.[30]

2.2 ANNUALIZED COST

This section presents the methods used to calculate the annualized costs for the standard boilers and control systems.

TABLE 2.1-9. SCREEN AREA, HORSEPOWER REQUIREMENT, AND EQUIPMENT COST (MID 1978$) FOR FLY ASH REINJECTION SYSTEMS

Model Boiler No.	Screen Area, ft^2	Horsepower Requirement	Equipment Costs	
			Screen	Motor
WOOD-30-MC (0.60)	24	3	7,200	150
WOOD-30-DM (0.40), WOOD-30-MC/WS (0.30), WOOD-30-MC/WS (0.15), WOOD-30-MC/WS (0.05)	18	3	7,100	150
WOOD-75-MC (0.60)	56	5	8,700	350
WOOD-75-DM (0.40), WOOD-75-MC/WS (0.30), WOOD-75-MC/WS (0.15), WOOD-75-MC/WS (0.05)	45	5	8,400	350
WOOD-150-MC (0.60)	112	15	13,400	540
WOOD-150-DM (0.40), WOOD-150-MC/WS (0.30), WOOD-150-MC/WS (0.15), WOOD-150-MC/WS (0.05)	90	5	10,300	350
WOOD-400-MC (0.60)	320	30	24,200	750
WOOD-400-DM (0.40), WOOD-400-MC/WS (0.30), WOOD-400-MC/WS (0.15), WOOD-400-MC/WS (0.05)	240	15	20,900	540

2.2.1 Annualized Cost Components

The annualized cost includes all the costs incurred in the yearly production of steam. These costs include direct and indirect operating costs and annual charges attributed to the initial capital expenditure. Components of the annualized cost are itemized in Table 2.2-1.

The capital recovery factors used in this report are based on an interest rate of 10 percent and a 15 year economic equipment life. Since all costs in this report are in constant 1978 dollars, this interest rate is in real dollars and represents the cost of capital above the general inflation rate.

Utility and unit operating costs used in this report are presented in Table 2.2-2.

2.2.2 Calculation of Annualized Costs for Annualized Costs for Boilers and Control Systems

2.2.2.1 Labor and maintenance costs. Labor costs for NFFBs are based on the labor costs for similar sized coal-fired boilers. Labor costs for uncontrolled model boilers are shown in Table 2.2-3. For bagasse-fired boilers the labor costs calculated from Table 2.2-3 are multiplied by 0.5 because these boilers operate only part of the year.

Costs of maintenance materials are calculated from the equations shown in Table 2.2-4. The equations are based on data from Reference 20 and data from boiler owners.

Costs of labor and maintenance materials for PM control systems are calculated using the equations shown in Table 2.2-5. The equations are based on Reference 24, data from boiler owners, and engineering judgement.

2.2.2.2 Electricity, chemicals, and process water costs. The combined cost of electricity chemicals and water for uncontrolled wood- and bagasse-fired boilers are calculated using the following equation:

$$\text{cost} = CF(29{,}303 + 719.8x)$$

where x is the system capacity in million Btu/hr and CF is the boiler capacity factor expressed as a decimal.

TABLE 2.2-1. ANNUALIZED COST COMPONENTS

(1) DIRECT OPERATING COSTS

- Operating Labor
- Supervision
- Maintenance Labor
- Maintenance Materials
- Electricity
- Chemicals
- Waste Disposal
    - Solids (fly ash and bottom ash)
    - Sludge
- Fuel

TOTAL DIRECT OPERATING COSTS

(2) INDIRECT OPERATING COSTS

- Payroll Overhead[a]
- Plant Overhead[b]

TOTAL INDIRECT OPERATING COSTS

(3) CAPITAL CHARGES

- G & A, Taxes, and Insurance[c]
- Interest on Working Capital[d]
- Capital Recovery Charges[e]

TOTAL CAPITAL CHARGES

TOTAL ANNUALIZED COSTS (Direct Operating Costs + Indirect Operating Costs + Capital Charges)

---

[a] Estimated as 30% of the sum of Direct Labor and Supervision.

[b] Estimated as 26% of the total of Direct Labor, Supervision, Maintenance Labor, and Maintenance Materials.

[c] Estimated as 4% of the Total Capital Cost.

[d] Estimated as i% of the Working Capital where i is the interest rate.

[e] Estimated as Capital Recovery Factor (CRF) x Total Capital Cost with the CRF calculated as follows:

$$\mathrm{CRF} = \frac{i(1 + i)^n}{(1 + i)^n - 1}$$

where: i is the interest rate and n is the life of the equipment.

TABLE 2.2-2. UTILITY AND UNIT OPERATING COSTS, MID-1978 $ BASIS[a]

(1) UTILITY COSTS	
- Electricity	$0.0258/kwh
- Water	$0.15/$10^3$ gal
(2) LABOR COSTS	
- Operating labor	$12.02/man-hour
- Maintenance labor	$14.63/man-hour
- Supervision labor	$15.63/man-hour
(3) FUEL COSTS	
- High Sulfur Eastern Coal[d]	$1.81/$10^6$ Btu
- Nonfossil Fuels	no cost[b]
(4) SOLID AND SLUDGE DISPOSAL COSTS (Landfill)[c]	
- Wood-fired Boilers (all sizes)	$20/ton
- MSW-fired Boilers (44 MW or 150 x 10^6 Btu/hr)	$12.50/ton
- MSW-fired Boilers (117 MW or 400 x 10^6 Btu/hr)	$9/ton
- Bagasse-fired Boilers (200 x 10^6 Btu/hr)	$10/ton
(5) CREDITS FOR NOT LANDFILLING MSW[c]	
- 44 MW or 150 x 10^6 Btu/hr	$9/ton
- 117 MW or 400 x 10^6 Btu/hr	$9/ton

[a] Except as noted, costs are based on PEDCo's Population and Characteristics of Industrial/Commercial Boilers in the U.S.[24]

[b] For many companies nonfossil fuels may have a value greater than zero. However, for this analysis the conservative approach is to assign no cost to the fuel. This approach reduces the uncontrolled boiler cost thereby increasing the impact of emission control costs.

[c] Unit landfill costs and credits are based on the unit costs and credits in EEA's Estimated Landfill Credit for Nonfossil Fuel Fired Boilers.[33] The costs for each boiler are based on the smallest-size landfill capable of absorbing ash and sludge from each model boiler. On-site landfills are assumed for all boilers except MSW-fired boilers. MSW-fired boilers feature off-site disposal 25 miles from the boiler site.

[d] This is the 1990 price in mid 1978 dollars.

TABLE 2.2-3. LABOR COSTS FOR UNCONTROLLED MODEL BOILERS[20]

	Boiler Capacity, MW (10^6 Btu/hr)				
	8.8(30)	220(75)	44.0(150)	58.6(200)	117(400)
Operating Labor[a]	1.5	2.25	3.25	4.25	6.75
Supervision[a]	0.5	1.0	1.0	1.0	1.5
Maintenance Labor[a]	0.5	0.75	1.0	1.5	3.0

[a] Values shown are workers per shift. Labor costs in $/yr are the product of the number of workers, 8760 hours per year, and the unit labor cost.

TABLE 2.2-4. MAINTENANCE MATERIALS COSTS FOR UNCONTROLLED MODEL BOILERS[a,b]

Cost of Maintenance Materials		
Fuel		
Wood	boiler $\leq 250 \times 10^6$ Btu/hr	cost = 50,000 + 1000x
	boiler $>250 \times 10^6$ Btu/hr	cost = 180,429 + 405.4x
Bagasse		cost = 450x
MSW		cost = 430x

[a] x = boiler heat input, 10^6 Btu/hr.

[b] Values are based on data from Reference 20 and boiler owner data.

TABLE 2.2-5. OPERATION AND MAINTENANCE COSTS FOR PM CONTROL SYSTEMS[a,b,c]

Item	Direct Labor Mid 1978 $/yr	Maintenance Labor Mid 1978 $/yr	Maintenance Materials Mid 1978 $/yr
MC[d,e]	5,075 + 53Q	$7,420 + 0.053Q^2$	0.005 (TDI + TII)
MC, WS; WS[d]	10,150 + 106Q	$14,840 + 0.106Q^2$	0.04 (TDI)
ESP	10,150 + 106Q	$14,840 + 0.106Q^2$	0.005 (TDI + TII)

[a] Q = boiler heat input capacity in 10^6 Btu/hr.
MC = mechanical collector.
WS = wet scrubber.
ESP = electrostatic precipitator.
MC, WS = a mechanical collector followed by a wet scrubber in series.

[b] The labor and maintenance materials costs for mechanical collectors are based on owner data and engineering judgement. Costs for other control devices are taken from "Capital and Operating Costs of Particulate Controls on Coal- and Oil-Fired Industrial Boilers."[24]

[c] The cost of supervisory labor in $/yr is estimated as 15 percent of direct labor costs in $/yr.

[d] The labor costs calculated using the above equations are multiplied by a factor of 0.5, and the maintenance materials cost by a factor of 0.85 when applied to bagasse-fired boilers. This is because bagasse-fired boilers operate only part of the year.

[e] The labor costs for a MC are multiplied by a factor of 1.5 when applied to DM control.

Costs of electricity, chemicals, and water for MSW-fired boilers are based on data from boiler owners. The owner data was used to develop the following factors:

(1) water demand = 1.79 gpm per 10^6 Btu/per hour of heat input

(2) electricity demand = 3.06 kW per 10^6 Btu per hour

(3) chemical cost = \$280 per million Btu per hour

The annual cost is calculated as the product of the above factor, annual heat input, and unit costs.

The electricity cost for PM control systems is calculated as the product of the total system energy demand, the boiler capacity factor, and the unit cost of electricity.

2.2.2.3 Fuel costs. Nonfossil fuels are assumed to have no cost. MSW-fired boiler costs include the cost of fossil fuel used for startup. The amount of fuel use is based on data from boiler owners and is 0.5 percent of the total annual boiler heat input. The fuel type is natural gas. The annual cost is calculated as the product of the annual fossil fuel heat input and the price of natural gas (\$2/10^6 Btu).

2.2.2.4 Solid waste disposal costs. The amount of solid waste produced per year is calculated based on the amount of solid waste produced at the rated boiler capacity and the boiler capacity factor. The amount of boiler bottom ash produced and boiler load factors are shown in Table 2.1-2. Table 2.2-6 shows the amounts of dry solid waste and sludge produced by emission controls. The cost of solid waste disposal is the product of the amount of solid waste produced per year and the disposal cost in \$/ton shown in Table 2.2-2.

In addition, boilers firing MSW receive a cost credit based on the money saved by not having to landfill the MSW. The amount of this credit in dollars per ton of MSW fired is shown in Table 2.2-2.

2.2.2.5 Other annualized costs. The remaining components of annualized costs are calculated as percentages of labor, maintenance, and capital costs. The factors used to calculate these costs are discussed in Section 2.2.1 and shown in Table 2.2-1.

TABLE 2.2-6. AMOUNTS OF SOLID WASTE PRODUCED BY PARTICULATE EMISSION CONTROLS

Model Boiler Number	Solids From Dry Particulate Controls (Tons/yr)[a,c]	Sludge From Wet Scrubbers (Tons/yr)[b]
WOOD-30-MC (0.60)	199	-
WOOD-30-DM (0.40)	215	-
WOOD-30-MC/WS (0.30)	169	178
WOOD-30-MC/WS (0.15)	169	215
WOOD-30-MC/WS (0.05)	169	242
WOOD-75-MC (0.60)	497	-
WOOD-75-DM (0.40)	536	-
WOOD-75-MC/WS (0.30)	423	444
WOOD-75-MC/WS (0.15)	423	539
WOOD-75-MC/WS (0.05)	423	604
WOOD-150-MC (0.60)	993	-
WOOD-150-DM (0.40)	1072	-
WOOD-150-MC/WS (0.30)	846	888
WOOD-150-MC/WS (0.15)	846	1080
WOOD-150-MC/WS (0.05)	846	1210
WOOD-400-MC (0.60)	2652	-
WOOD-400-DM (0.40)	2862	-
WOOD-400-MC/WS (0.30)	2260	2369
WOOD-400-MC/WS (0.15)	2260	2870
WOOD-400-MC/WS (0.05)	2260	3220
MSW-150-ESP (0.17)	1260	-
MSW-150-ESP (0.10)	1280	-
MSW-150-ESP (0.05)	1310	-
MSW-400-ESP (0.17)	3350	-
MSW-400-ESP (0.10)	3430	-
MSW-400-ESP (0.05)	3490	-
BAG-200-MC (0.62)	1750	-
BAG-200-WS (0.30)	-	3745[d]
BAG-200-WS (0.20)	-	3824[d]

[a] Weight on a dry basis.

[b] Weight based on a 30 percent solids sludge.

[c] For wood-fired boilers a portion of the fly ash collected by the mechanical collector is burned by reinjection. This reduces the amount of solid waste generated.

[d] Weight based on a 50 percent solids sludge.

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3.0 COSTS OF PM CONTROL SYSTEMS AND UNCONTROLLED BOILERS

This chapter presents the results of the model boiler cost analysis for uncontrolled NFFBs and the associated PM control systems. This analysis focuses on the capital cost, annual operation and maintenance (O&M) costs, and total annualized cost of control for boilers firing either wood, municipal solid waste (MSW), or bagasse. The PM control technologies examined for each fuel type are presented in Section 1.2.2. Detailed design specifications for boilers and control systems were presented in Sections 2.1.2 and 2.1.3 respectively.

In addition to the model boiler cost cases shown in Sections 1 and 2, costs are also shown for certain additional cases. These cases include wood-fired boilers with mechanical collectors followed by wet scrubbers (MC/WS) controlled to emission levels of 0.2 and 0.1 lb/10^6 Btu. The costs for these cases were not developed using the costing methods shown in Section 2, but were interpolated from the costs for the other wood-fired boiler MC/WS model boiler cases. The two additional wood-fired boiler cases were included because the emission levels of 0.2 and 0.1 were considered as regulatory options.

All costs in this chapter are presented as mid-1978 dollars. Bagasse-fired boilers are assumed to have a capacity utilization factor of 0.45. All other boilers have capacity utilization factors of 0.6. All boilers and control equipment are assumed to have a capital recovery factor of 0.1315 which is based on an economic equipment life of 15 years and a 10 percent rate of return on capital. All costs shown for wet scrubbers applied to wood-fired boilers include the cost of the mechanical collector precleaner.

3.1 CAPITAL COSTS OF BOILERS AND CONTROLS

Table 3-1 presents the capital costs for uncontrolled NFFBs and PM control systems applied to NFFBs. Table 3-1 shows that costs on a unit capacity basis decrease with system size due to boiler and emission controls

TABLE 3-1. CAPITAL COSTS FOR MODEL BOILERS

Model Boiler	Capital Costs ($1000) Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	% Increase Over Uncontrolled
WOOD-30-MC (0.60)	1800	96	1896	63.2	5.3
WOOD-30-DM (0.40)	1800	141	1941	64.7	7.8
WOOD-30-MC/WS (0.30)	1800	314	2114	70.5	17.4
WOOD-30-MC/WS (0.20)[b]	1800	356	2156	71.9	19.8
WOOD-30-MC/WS (0.15)	1800	366	2166	72.2	20.3
WOOD-30-MC/WS (0.10)[b]	1800	376	2176	72.5	20.9
WOOD-30-MC/WS (0.05)	1800	389	2189	73.0	21.6
WOOD-75-MC (0.60)	3660	155	3815	50.9	4.2
WOOD-75-DM (0.40)	3660	243	3903	52.0	6.6
WOOD-75-MC/WS (0.30)	3660	489	4149	55.3	13.4
WOOD-75-MC/WS (0.20)[b]	3660	543	4203	56.0	14.8
WOOD-75-MC/WS (0.15)	3660	563	4223	56.3	15.4
WOOD-75-MC/WS (0.10)[b]	3660	584	4244	56.6	16.0
WOOD-75-MC/WS (0.05)	3660	617	4277	57.0	16.9
WOOD-150-MC (0.60)	6130	309	6439	42.9	5.0
WOOD-150-DM (0.40)	6130	442	6572	43.8	7.2
WOOD-150-MC/WS (0.30)	6130	748	6878	45.9	12.2
WOOD-150-MC/WS (0.20)[b]	6130	836	6966	46.4	13.6
WOOD-150-MC/WS (0.15)	6130	880	7010	46.7	14.4
WOOD-150-MC/WS (0.10)[b]	6130	936	7066	47.1	15.3
WOOD-150-MC/WS (0.05)	6130	1039	7169	47.8	16.9
WOOD-400-MC (0.60)	13500	668	14168	35.4	4.9
WOOD-400-DM (0.40)	13500	998	14498	36.2	7.4
WOOD-400-MC/WS (0.30)	13500	1419	14919	37.3	10.5
WOOD-400-MC/WS (0.20)[b]	13500	1623	15123	37.8	12.0
WOOD-400-MC/WS (0.15)	13500	1700	15200	38.0	12.6
WOOD-400-MC/WS (0.10)[b]	13500	1784	15284	38.2	13.2
WOOD-400-MC/WS (0.05)	13500	1927	15427	38.6	14.3

TABLE 3-1. CAPITAL COSTS FOR MODEL BOILERS (CONTINUED)

Model Boiler	Capital Costs ($1000)				% Increase Over Uncontrolled
	Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	
MSW-150-ESP (0.17)	16500	1050	17550	117.0	6.4
MSW-150-ESP (0.10)	16500	1136	17636	117.6	6.9
MSW-150-ESP (0.05)	16500	1367	17867	119.1	8.3
MSW-400-ESP (0.17)	35300	1696	36996	92.5	4.8
MSW-400-ESP (0.10)	35300	2181	37481	93.7	6.2
MSW-400-ESP (0.05)	35300	2984	38284	95.7	8.5
BAG-200-MC (0.62)	5450	398	5848	29.2	7.3
BAG-200-WS (0.30)	5450	543	5993	30.0	10.0
BAG-200-WS (0.20)	5450	545	5995	30.0	10.0

[a] Normalized total is total capital cost divided by boiler capacity ($1000/$10^6$ Btu/hr).

[b] Interpolated result from Figure 3-6.

economies of scale. Table 3-1 also shows that emission controls required for more stringent levels of control are more expensive than controls required for less stringent levels of control.

The uncontrolled MSW-fired boilers have significantly higher capital costs than the other boiler types shown. This is because MSW-fired boilers have different designs from wood- and bagasse-fired boilers.

Wet scrubbers applied to uncontrolled wood-fired boilers show more significant cost impacts over mechanical collectors than wet scrubbers applied to bagasse-fired boilers. This is because the wood-fired boiler wet scrubber costs include the cost of a thickener used only for scrubber waste water treatment. The thickener produces a sludge that is mixed with the boiler bottom ash and landfilled and the thickener overflow is recycled to the wet scrubber. Therefore, there is no waste water discharge for this system. This design was used for wood-fired boilers because they are located in many different types of facilities which will not necessarily have an alternative waste water treatment system available. For new wood-fired boilers located at sites where other water treatment systems are available the thickener would not be required and the wet scrubber capital costs would be significantly reduced. Table 3-2 shows a comparison of wet scrubber capital costs with and without a thickener.

For bagasse-fired boilers the situation is different. Bagasse-fired boilers are always located in sugar mills. Sugar mills provide several waste water treatment alternatives for scrubber water discharges. These are:

- treatment with the water used to wash the sugar cane
- using the water for irrigation
- disposing of the water in unused fields next to the plant

Because one or more of these alternatives will be available at a sugar mill the cost of a separate water treatment facility was not included in the costs of a wet scrubber for bagasse-fired boilers. The cost of piping scrubber waste water to treatment disposal, and the cost of landfilling the sludge which would result are included in the costs.

TABLE 3-2. COMPARISON OF WET SCRUBBER CAPITAL COSTS WITH AND WITHOUT THICKENERS FOR A 150 x 10^6 Btu/hr WOOD-FIRED BOILER[a]

Model Boiler	Capital Cost ($1000)		
	With Thickener	Without Thickener	Percent Decrease
WOOD-150-MC/WS (0.30)	748	526	29.7
WOOD-150-MC/WS (0.15)	880	642	27.0
WOOD-150/MC/WS (0.05)	1039	791	23.9

[a] Wet scrubber costs include the cost of the mechanical collector precleaner.

Figures 3-1 through 3-5 show uncontrolled boiler and PM emission control costs as a function of boiler size. These figures can be used to estimate boiler and control systems costs at boiler sizes not shown in Table 3-1. The relationship between the PM emission level and wet scrubber pressure drop or ESP specific collection area is shown in Table 3-3. In addition, Figure 3-6 shows wet scrubber pressure drop versus wet scrubber control system capital cost. This figure can be used to estimate wet scrubber capital costs at different scrubber pressure drops.

3.2 O&M AND TOTAL ANNUALIZED COSTS OF BOILERS AND PM CONTROLS

Annual O&M costs for NFFBs are presented in Table 3-4. For each uncontrolled wood-fired model boiler two annual O&M costs are shown. The first O&M cost is based on the assumption that the wood fuel has no cost. The second value shows the annual O&M cost if the wood fuel is assumed to have a cost equal to HSC on a $/Btu basis. The actual cost of wood fuels is expected to fall somewhere between no cost and a cost equal to HSC for a majority of new wood-fired boilers. The normalized annual costs provide a size independent measure of the annual O&M costs of the boiler and pollution control system. Normalized annual costs ($1,000/yr) are computed by dividing the annual cost by the annual heat input (10^6 Btu/yr).

Total annualized costs, which include annual capital charges, are presented in a similar manner in Table 3-5. The normalized annualized costs decrease with boiler size indicating economies of scale with larger boilers. Two different annualized costs are shown for each uncontrolled wood-fired boiler. One for the case where the wood fuel is assumed to have no cost, and one for the case where the cost of the wood fuel is assumed to be equal to the cost of HSC.

MSW-fired boilers have lower annualized costs than wood-fired boilers even though the capital costs for MSW-fired boilers were much higher than those for wood. The low annualized costs for MSW-fired boilers result from a cost credit that is included in the annualized cost of these boilers. This cost credit accounts for money saved by burning MSW rather than landfilling it.

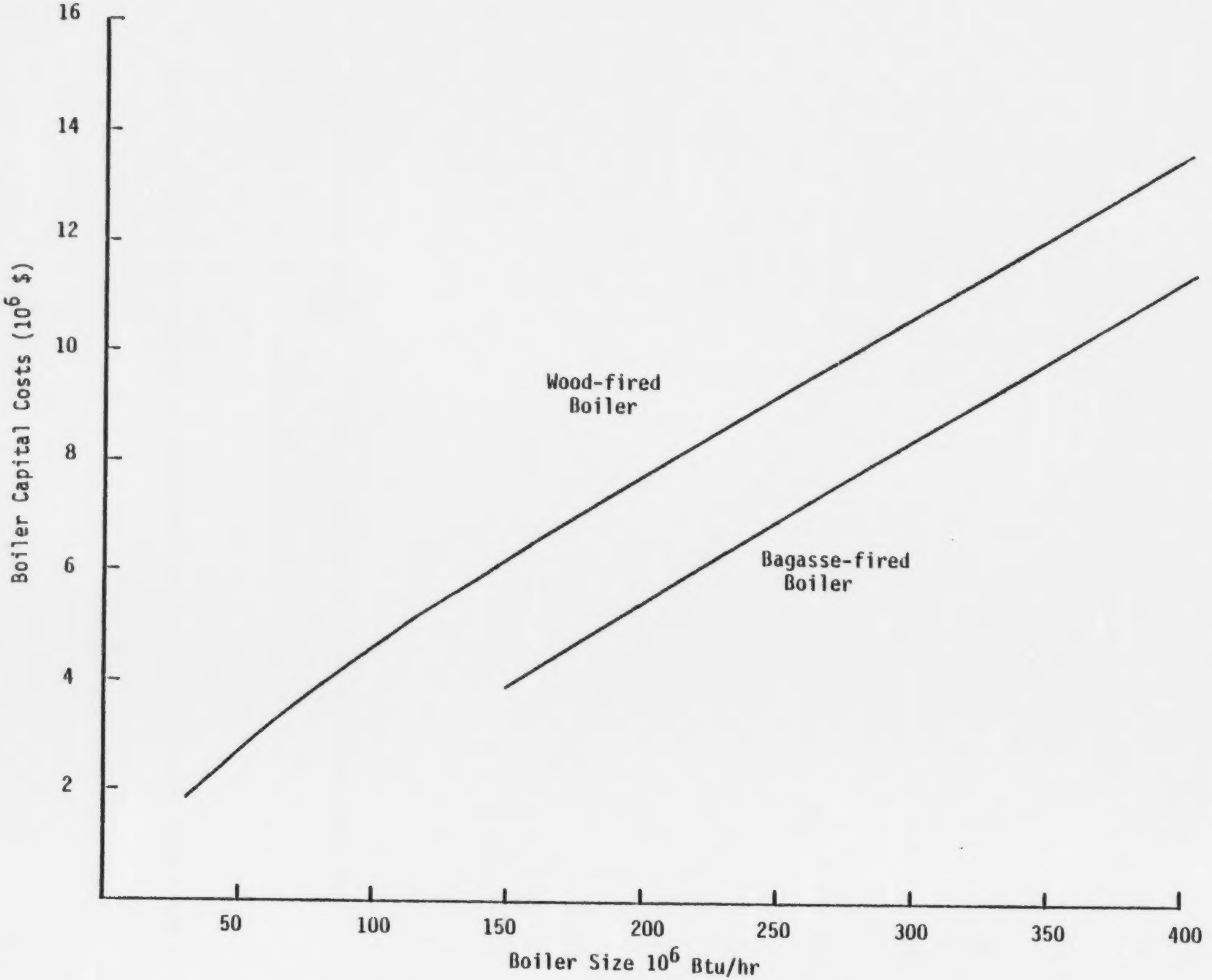


Figure 3-1. Wood- and bagasse-fired boiler capital costs as a function of boiler size.

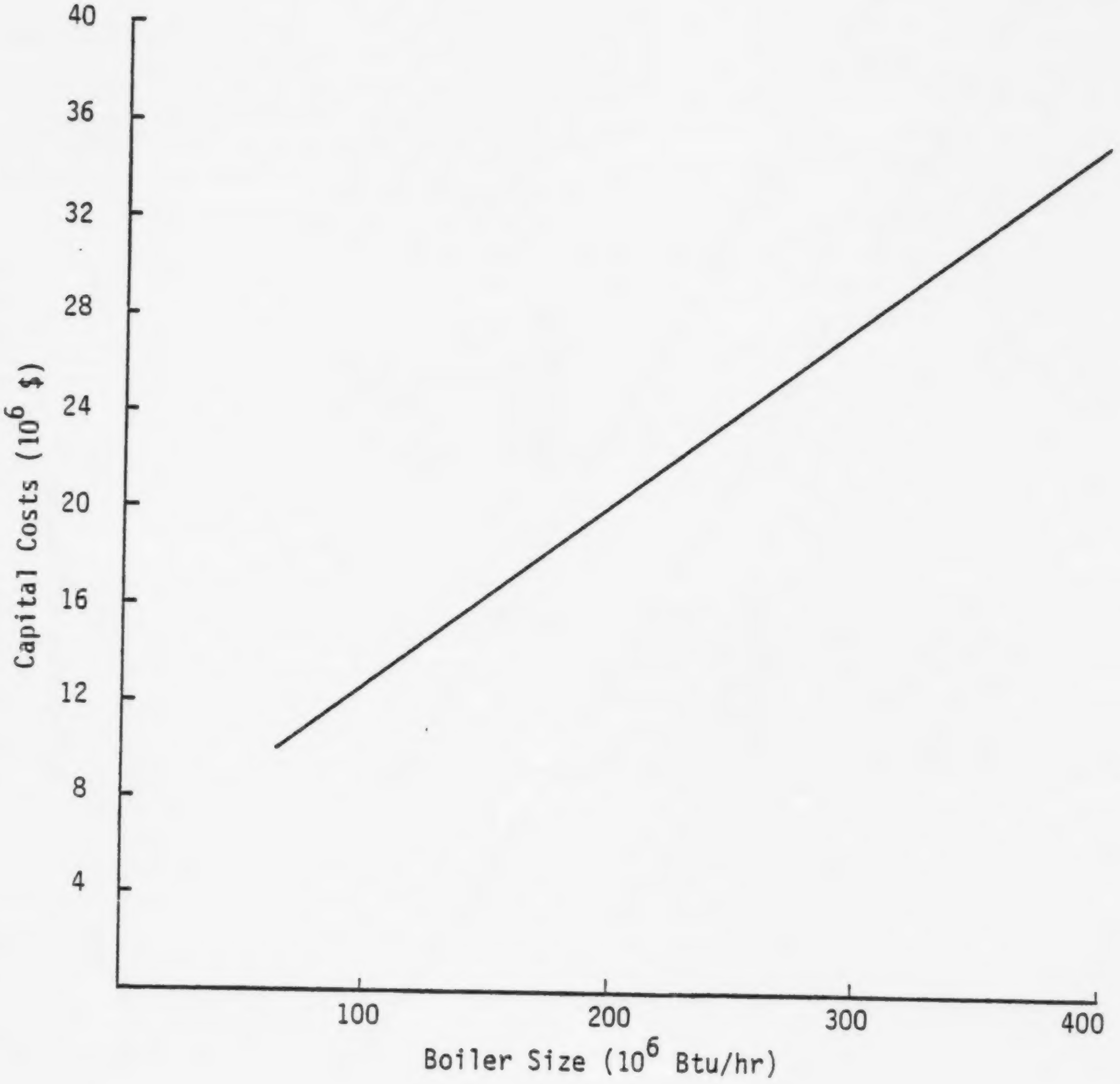
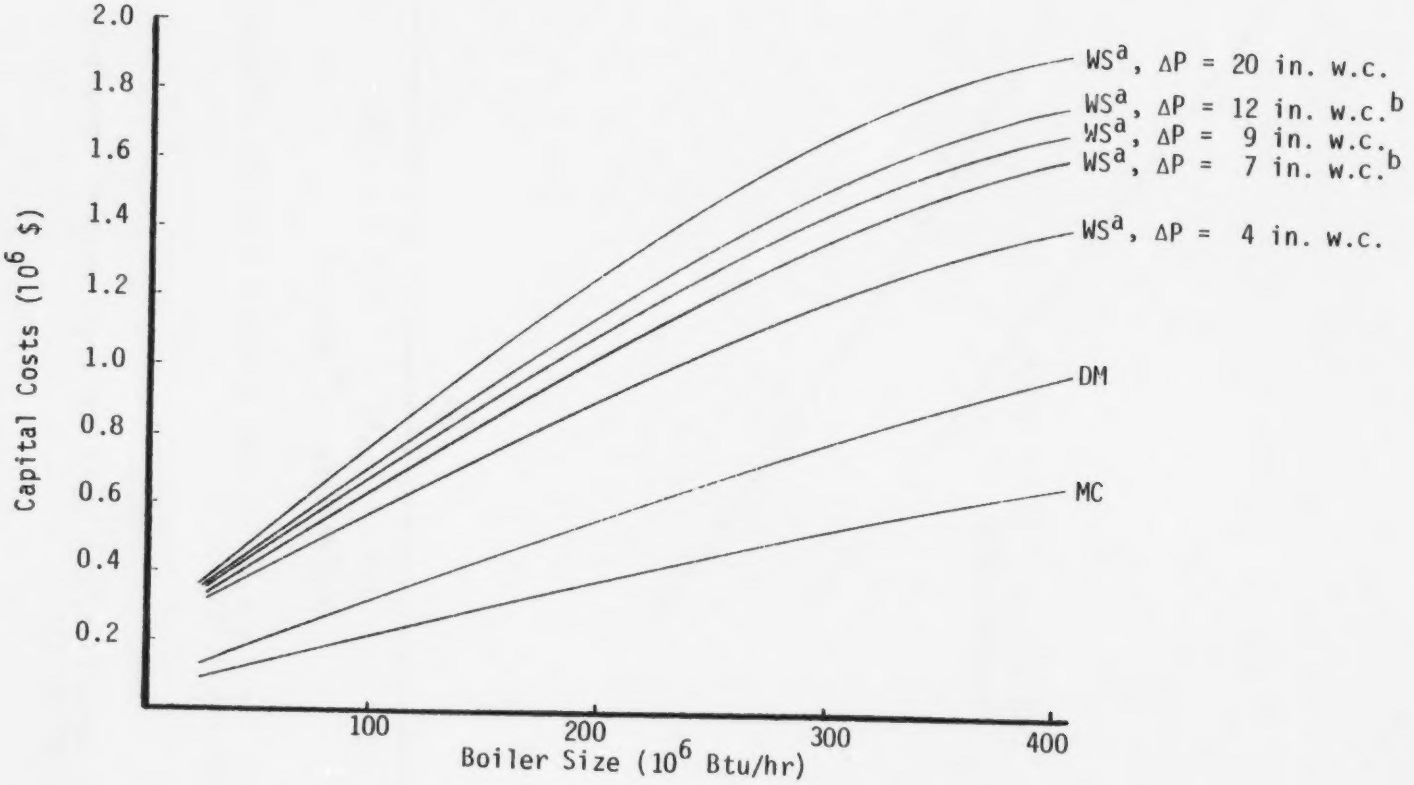
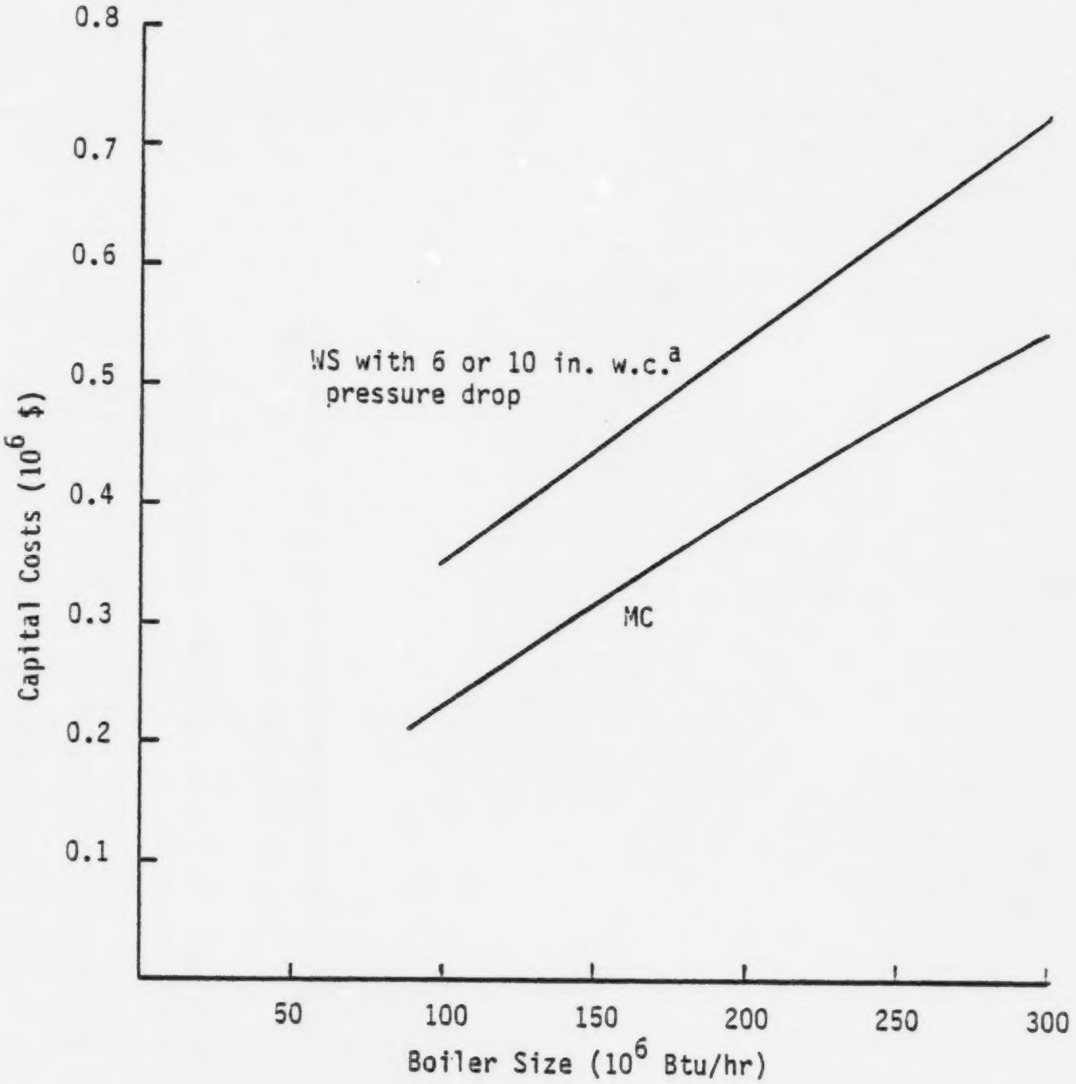


Figure 3-2. MSW-fired boiler capital costs as a function of boiler size.



[a] These control systems include an upstream mechanical collector.
[b] Based on interpolated values.

Figure 3-3. Capital costs of PM controls applied to wood-fired boilers as a function of boiler size.



[a] Capital costs for 6 and 10 in. w.c. pressure drop wet scrubbers are approximately equivalent.

Figure 3-4. PM control capital costs for bagasse-fired boilers as a function of boiler size.

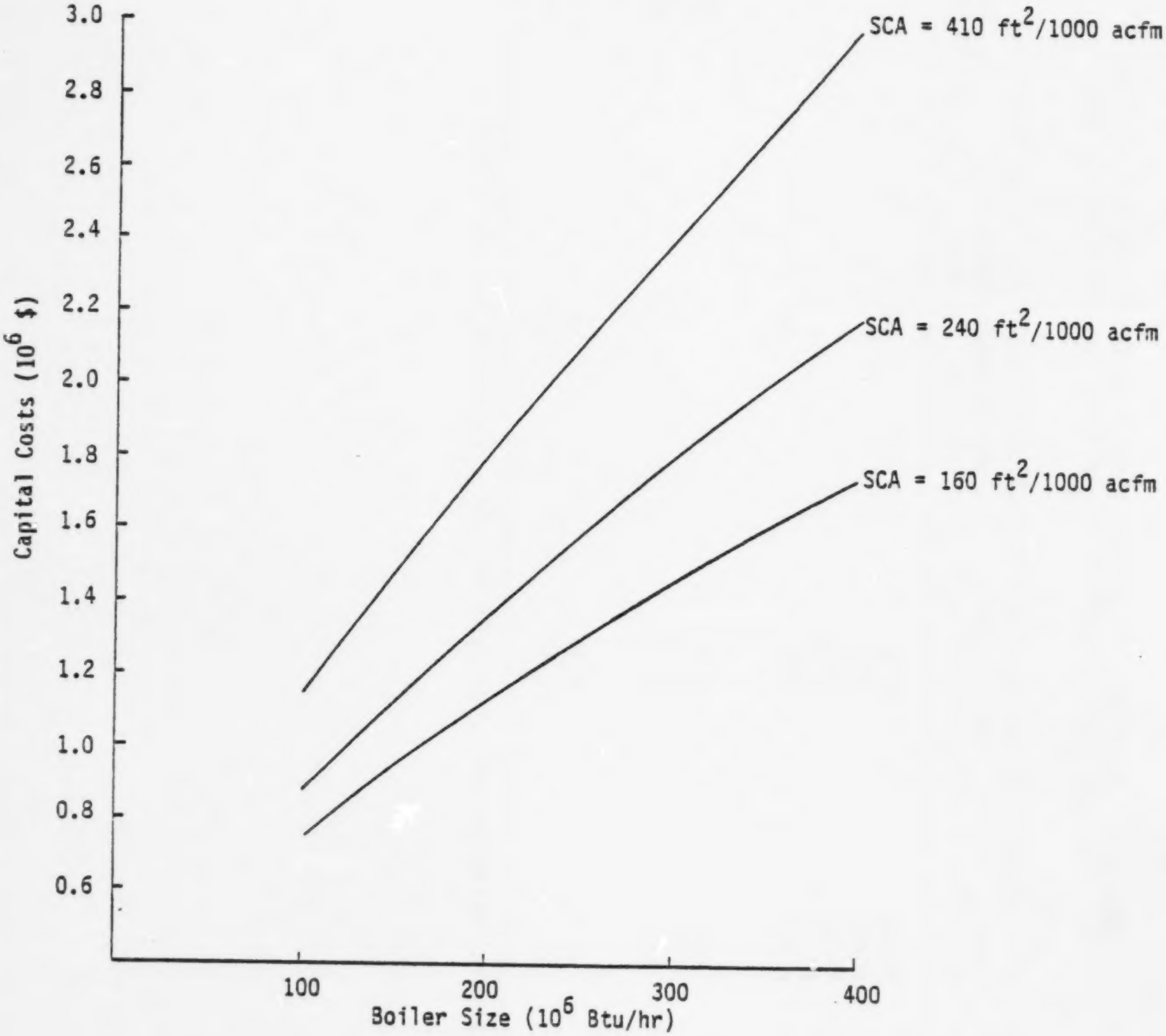


Figure 3-5. Capital costs of ESP's applied to MSW-fired boilers as a function of boiler size.

TABLE 3-3. RELATIONSHIP BETWEEN PM EMISSION LEVELS AND WET SCRUBBER PRESSURE DROP OR ELECTROSTATIC PRECIPITATOR SCA FOR NONFOSSIL FUELS

Fuel	Control Device[a]	PM Emission Level (lb/10^6 Btu)	Wet Scrubber Pressure Drop (in. w.c.)	SCA (ft^3/1000 acfm)
WOOD	MC/WS	0.30	4	-
WOOD	MC/WS	0.20	7	-
WOOD	MC/WS	0.15	9	-
WOOD	MC/WS	0.10	12	-
WOOD	MC/WS	0.05	20	
MSW	ESP	0.17	-	160
MSW	ESP	0.10	-	240
MSW	ESP	0.05	-	410
BAG	WS	0.30	6	-
BAG	WS	0.20	10	-

[a] MC - mechanical collector; WS - wet scrubber; ESP - electrostatic precipitator.

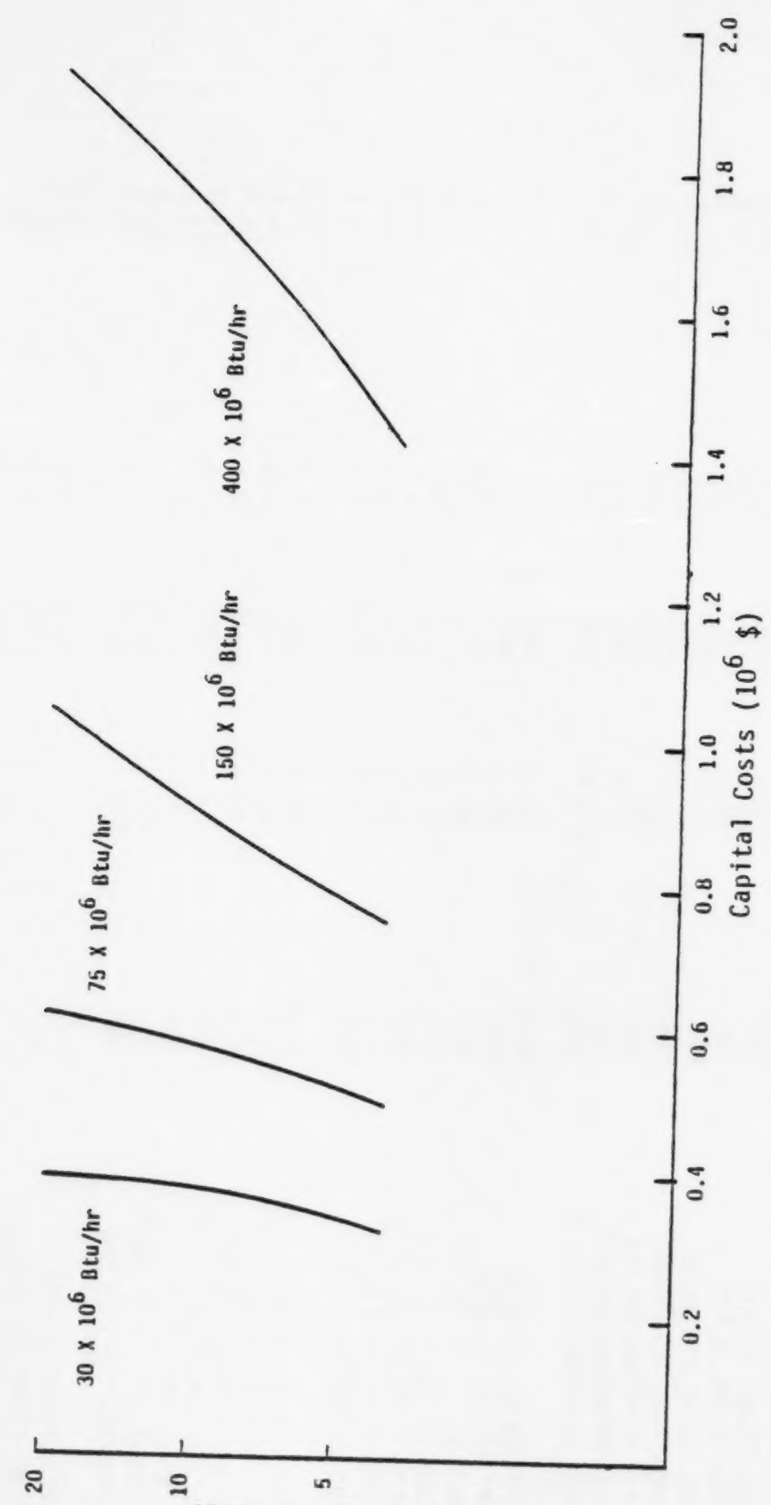


Figure 3-6. Wet scrubber capital costs versus pressure drop for four boiler sizes.

TABLE 3-4. ANNUAL O&M COSTS FOR MODEL BOILERS

Model Boiler	Annual Costs ($1000/yr)				% Increase Over Uncontrolled
	Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	
WOOD-30-MC (0.60)	568[b]	28.5	596	3.8	5.0
WOOD-30-DM (0.40)	568	40.9	609	3.9	7.2
WOOD-30-MC/WS (0.30)	568	63.9	632	4.0	11.2
WOOD-30-MC/WS (0.20)[d]	568	67.0	635	4.0	11.8
WOOD-30-MC/WS (0.15)	568	70.2	638	4.0	12.4
WOOD-30-MC/WS (0.10)[d]	568	72.0	640	4.1	12.7
WOOD-30-MC/WS (0.05)	568	76.4	644	4.1	13.5
WOOD-30-MC (0.60)	853[c]	28.5	881	5.6	3.3
WOOD-30-DM (0.40)	853	40.9	894	5.7	4.8
WOOD-30-MC/WS (0.30)	853	63.9	917	5.8	7.5
WOOD-30-MC/WS (0.20)[d]	853	67.0	920	5.8	7.9
WOOD-30-MC/WS (0.15)	853	70.2	923	5.9	8.2
WOOD-30-MC/WS (0.10)[d]	853	72.0	925	5.9	8.4
WOOD-30-MC/WS (0.05)	853	76.4	929	5.9	8.9
WOOD-75-MC (0.60)	918[b]	42.4	960	2.4	4.6
WOOD-75-DM (0.40)	918	60.0	978	2.5	6.5
WOOD-75-MC/WS (0.30)	918	95.5	1014	2.6	10.4
WOOD-75-MC/WS (0.20)[d]	918	104	1022	2.6	11.3
WOOD-75-MC/WS (0.15)	918	110	1028	2.6	12.0
WOOD-75-MC/WS (0.10)[d]	918	116	1034	2.6	12.6
WOOD-75-MC/WS (0.05)	918	125	1043	2.6	13.6
WOOD-75-MC (0.60)	1632[c]	42.4	1674	4.2	2.6
WOOD-75-DM (0.40)	1632	60.0	1692	4.3	3.7
WOOD-75-MC/WS (0.30)	1632	95.5	1728	4.4	5.9
WOOD-75-MC/WS (0.20)[d]	1632	104	1736	4.4	6.4
WOOD-75-MC/WS (0.15)	1632	110	1742	4.4	6.7
WOOD-75-MC/WS (0.10)[d]	1632	116	1748	4.4	7.1
WOOD-75-MC/WS (0.05)	1632	125	1757	4.5	7.7

TABLE 3-4. ANNUAL O&M COSTS FOR MODEL BOILERS (CONTINUED)

Model Boiler	Annual Costs ($1000/yr)				% Increase Over Uncontrolled
	Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	
WOOD-150-MC (0.60)	1255[b]	68.2	1323	1.7	5.4
WOOD-150-DM (0.40)	1255	92.8	1348	1.7	7.4
WOOD-150-MC/WS (0.30)	1255	148	1403	1.8	11.8
WOOD-150-MC/WS (0.20)[d]	1255	165	1420	1.8	13.1
WOOD-150-MC/WS (0.15)	1255	176	1431	1.8	14.0
WOOD-150-MC/WS (0.10)[d]	1255	189	1444	1.8	15.1
WOOD-150-MC/WS (0.05)	1255	209	1464	1.9	16.7
WOOD-150-MC (0.60)	2682[c]	68.2	2750	3.5	2.5
WOOD-150-DM (0.40)	2682	92.8	2775	3.5	7.4
WOOD-150-MC/WS (0.30)	2682	148	2830	3.6	5.5
WOOD-150-MC/WS (0.20)[d]	2682	165	2847	3.6	6.2
WOOD-150-MC/WS (0.15)	2682	176	2858	3.6	6.6
WOOD-150-MC/WS (0.10)[d]	2682	189	2871	3.6	7.0
WOOD-150-MC/WS (0.05)	2682	209	2891	3.7	7.8
WOOD-400-MC (0.60)	2545[b]	156	2701	1.3	6.1
WOOD-400-DM (0.40)	2545	211	2756	1.3	8.3
WOOD-400-MC/WS (0.30)	2545	329	2874	1.4	12.9
WOOD-400-MC/WS (0.20)[d]	2545	371	2916	1.4	14.6
WOOD-400-MC/WS (0.15)	2545	401	2946	1.4	15.8
WOOD-400-MC/WS (0.10)[d]	2545	432	2977	1.4	17.0
WOOD-400-MC/WS (0.05)	2545	482	3027	1.4	18.9
WOOD-400-MC (0.60)	6350[c]	156	6506	3.1	2.5
WOOD-400-DM (0.40)	6350	211	6561	3.1	3.3
WOOD-400-MC/WS (0.30)	6350	329	6679	3.2	5.2
WOOD-400-MC/WS (0.20)[d]	6350	371	6721	3.2	5.8
WOOD-400-MC/WS (0.15)	6350	401	6751	3.2	6.3
WOOD-400-MC/WS (0.10)[d]	6350	432	6782	3.2	6.8
WOOD-400-MC/WS (0.05)	6350	482	6832	3.2	7.6

TABLE 3-4. ANNUAL O&M COSTS FOR MODEL BOILERS (CONTINUED)

Model Boiler	Annual Costs ($1000/yr)				% Increase Over Uncontrolled
	Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	
MSW-150-ESP (0.17)	1148	104	1252	1.6	9.1
MSW-150-ESP (0.10)	1148	108	1256	1.6	9.4
MSW-150-ESP (0.05)	1148	116	1264	1.6	10.1
MSW-400-ESP (0.17)	2941	211	3152	1.5	7.2
MSW-400-ESP (0.10)	2941	222	3163	1.5	7.5
MSW-400-ESP (0.05)	2941	244	3185	1.5	8.3
BAG-200-MC (0.62)	787	53.2	840	1.1	6.8
BAG-200-WS (0.30)	787	111	898	1.1	14.1
BAG-200-WS (0.20)	787	121	908	1.2	15.4

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[a] Normalized total is total annual cost divided by the annual boiler heat input ($/10^6 Btu).

[b] Annualized model boiler costs if the wood fuel is assumed to have no cost.

[c] Annualized model boiler costs if the wood fuel is assumed to cost the same as high sulfur eastern coal on a $/Btu basis.

[d] Interpolated from annual O&M costs presented for WOOD-MC/WS (0.30), WOOD-MC/WS (0.15), and WOOD-MC/WS (0.05).

TABLE 3-5. TOTAL ANNUALIZED COSTS FOR MODEL BOILERS

Model Boiler	Annualized Costs ($1000/yr)				% Increase Over Uncontrolled
	Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	
WOOD-30-MC (0.60)	886[b]	45.6	932	5.9	5.1
WOOD-30-DM (0.40)	886	65.9	952	6.0	7.4
WOOD-30-MC/WS (0.30)	886	119	1005	6.4	13.4
WOOD-30-MC/WS (0.20)[d]	886	130	1016	6.4	14.7
WOOD-30-MC/WS (0.15)	886	134	1020	6.5	15.1
WOOD-30-MC/WS (0.10)[d]	886	138	1024	6.5	15.6
WOOD-30-MC/WS (0.05)	886	145	1031	6.5	16.4
WOOD-30-MC (0.60)	1171[c]	45.6	1217	7.7	3.9
WOOD-30-DM (0.40)	1171	65.9	1237	7.8	5.6
WOOD-30-MC/WS (0.30)	1171	119	1290	8.2	10.2
WOOD-30-MC/WS (0.20)[d]	1171	130	1301	8.3	11.1
WOOD-30-MC/WS (0.15)	1171	134	1305	8.3	11.4
WOOD-30-MC/WS (0.10)[d]	1171	138	1309	8.3	11.8
WOOD-30-MC/WS (0.05)	1171	145	1316	8.3	12.4
WOOD-75-MC (0.60)	1562[b]	69.9	1632	4.1	4.5
WOOD-75-DM (0.40)	1562	103	1665	4.2	6.6
WOOD-75-MC/WS (0.30)	1562	181	1743	4.4	11.6
WOOD-75-MC/WS (0.20)[d]	1562	201	1763	4.5	12.9
WOOD-75-MC/WS (0.15)	1562	208	1770	4.5	13.3
WOOD-75-MC/WS (0.10)[d]	1562	218	1780	4.5	14.0
WOOD-75-MC/WS (0.05)	1562	234	1796	4.6	15.0
WOOD-75-MC (0.60)	2276[c]	69.9	2346	6.0	3.1
WOOD-75-DM (0.40)	2276	103	2379	6.0	4.5
WOOD-75-MC/WS (0.30)	2276	181	2457	6.2	8.0
WOOD-75-MC/WS (0.20)[d]	2276	201	2477	6.3	8.8
WOOD-75-MC/WS (0.15)	2276	208	2484	6.3	9.1
WOOD-75-MC/WS (0.10)[d]	2276	218	2494	6.3	9.6
WOOD-75-MC/WS (0.05)	2276	234	2510	6.4	10.3

TABLE 3-5. TOTAL ANNUALIZED COSTS FOR MODEL BOILERS (CONTINUED)

Model Boiler	Annualized Costs ($1000/yr) Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	% Increase Over Uncontrolled
WOOD-150-MC (0.60)	2329[b]	123	2452	3.1	5.3
WOOD-150-DM (0.40)	2329	171	2500	3.2	7.3
WOOD-150-MC/WS (0.30)	2329	280	2609	3.3	12.0
WOOD-150-MC/WS (0.20)[d]	2329	313	2642	3.4	13.4
WOOD-150-MC/WS (0.15)	2329	331	2660	3.4	14.2
WOOD-150-MC/WS (0.10)[d]	2329	352	2681	3.4	15.1
WOOD-150-MC/WS (0.05)	2329	391	2720	3.4	16.8
WOOD-150-MC (0.60)	3756[c]	123	3879	4.9	3.3
WOOD-150-DM (0.40)	3756	171	3927	5.0	4.6
WOOD-150-MC/WS (0.30)	3756	280	4036	5.1	7.5
WOOD-150-MC/WS (0.20)[d]	3756	313	4069	5.2	8.3
WOOD-150-MC/WS (0.15)	3756	331	4087	5.2	8.8
WOOD-150-MC/WS (0.10)[d]	3756	352	4108	5.2	9.4
WOOD-150-MC/WS (0.05)	3756	391	4147	5.3	10.4
WOOD-400-MC (0.60)	4906[b]	274	5180	2.5	5.6
WOOD-400-DM (0.40)	4906	387	5293	2.5	7.9
WOOD-400-MC/WS (0.30)	4906	579	5485	2.6	11.8
WOOD-400-MC/WS (0.20)[d]	4906	664	5570	2.6	13.5
WOOD-400-MC/WS (0.15)	4906	701	5607	2.7	14.3
WOOD-400-MC/WS (0.10)[d]	4906	745	5651	2.7	15.2
WOOD-400-MC/WS (0.05)	4906	823	5729	2.7	16.8
WOOD-400-MC (0.60)	8711[c]	274	8985	4.3	3.1
WOOD-400-DM (0.40)	8711	387	9098	4.3	4.4
WOOD-400-MC/WS (0.30)	8711	579	9290	4.4	6.6
WOOD-400-MC/WS (0.20)[d]	8711	664	9375	4.5	7.6
WOOD-400-MC/WS (0.15)	8711	701	9412	4.5	8.0
WOOD-400-MC/WS (0.10)[d]	8711	745	9456	4.5	8.6
WOOD-400-MC/WS (0.05)	8711	823	9534	4.5	9.4

TABLE 3-5. TOTAL ANNUALIZED COSTS FOR MODEL BOILERS (CONTINUED)

Model Boiler	Annualized Costs ($1000/yr)				% Increase Over Uncontrolled
	Uncontrolled Boiler	PM Emission Controls	Total	Normalized[a] Total	
MSW-150-ESP (0.17)	2086	286	2372	3.0	13.7
MSW-140-ESP (0.10)	2086	304	2390	3.0	14.6
MSW-140-ESP (0.05)	2086	352	2438	3.1	16.9
MSW-400-ESP (0.17)	3953	506	4459	2.1	12.8
MSW-400-ESP (0.10)	3953	601	4554	2.2	15.2
MSW-400-ESP (0.05)	3953	761	4714	2.2	19.3
BAG-200-MC (0.62)	1736	123	1859	2.4	7.1
BAG-200-WS (0.30)	1736	207	1943	2.5	11.9
BAG-200-WS (0.20)	1736	217	1953	2.5	12.5

[a] Normalized total is total annualized cost divided by the annual boiler heat input ($\$/10^6$ Btu).

[b] Annualized model boiler costs if the wood fuel is assumed to have no cost.

[c] Annualized model boiler costs if the wood fuel is assumed to cost the same as high sulfur eastern coal on a $/Btu basis.

[d] Interpolated result from Figure 3-11.

Wood-fired model boilers show total annualized cost increases ranging from 4.5 to 16.8 percent of the uncontrolled boiler costs if the wood fuel is assumed to have no cost. However, if wood fuel is assumed to have a cost equal to HSC ($/Btu basis), the total annualized model boiler cost increases over the uncontrolled boilers are reduced to 3.1 to 12.4 percent. As shown, assigning a value to nonfossil fuels significantly reduces the percentage increase in costs due to emission controls.

As discussed in Section 3.1, wet scrubbers applied to wood-fired boilers incur significant capital costs due to the requirement to treat the scrubber waste water. The impact of waste water treatment (thickener) costs on total annualized costs is shown in Table 3-6.

Figures 3-7 through 3-10 show uncontrolled boiler and PM control system annualized costs as a function of boiler size. These figures may be used to estimate annualized costs for boiler sizes not shown in Table 3-5.

Figure 3-11 shows wet scrubber annualized costs versus scrubber pressure drop. This figure can be used to estimate wet scrubber annualized costs at different scrubber pressure drops.

TABLE 3-6. COMPARISON OF MODEL BOILER ANNUALIZED COSTS WITH AND WITHOUT WET SCRUBBER THICKENERS FOR A 150 x 10^6 Btu/hr WOOD-FIRED BOILER

Model Boiler	Annualized Cost ($1000/yr)		
	With Thickener	Without Thickener	Percent Decrease
WOOD-150-MC/WS (0.30)	2609	2563	1.8
WOOD-150-MC/WS (0.15)	2660	2611	1.8
WOOD-150-MC/WS (0.05)	2720	2670	1.8

[a] Wet scrubber costs include the cost of the mechanical collector precleaner.

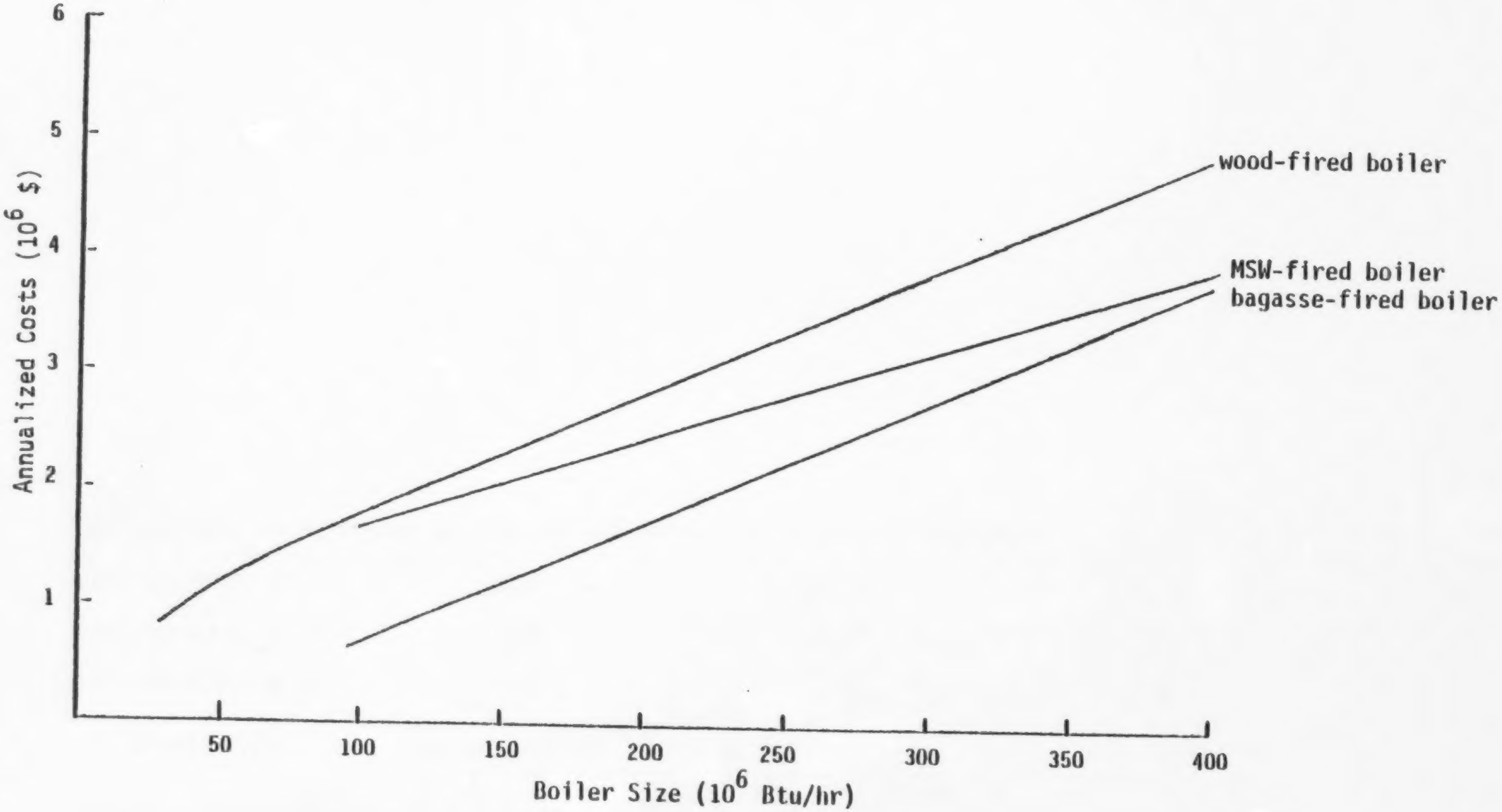
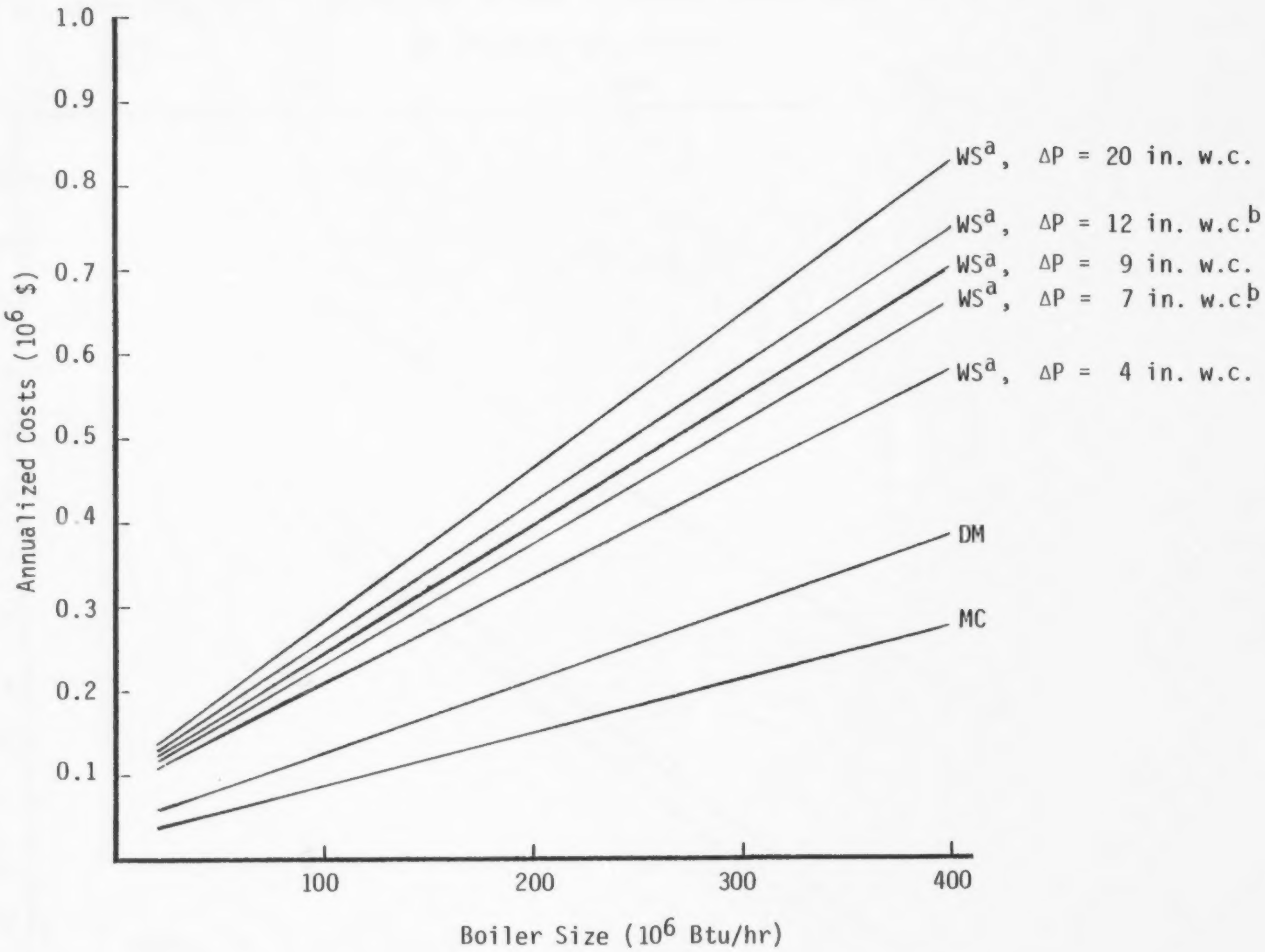


Figure 3-7. Wood-, bagasse-, and MSW-fired boiler annualized costs as a function of boiler size.



[a] These control systems include an upstream mechanical collector.
[b] Based on interpolated values from Figure 3-11.

Figure 3-8. Annualized costs of PM controls applied to wood-fired boilers as a function of boiler size.

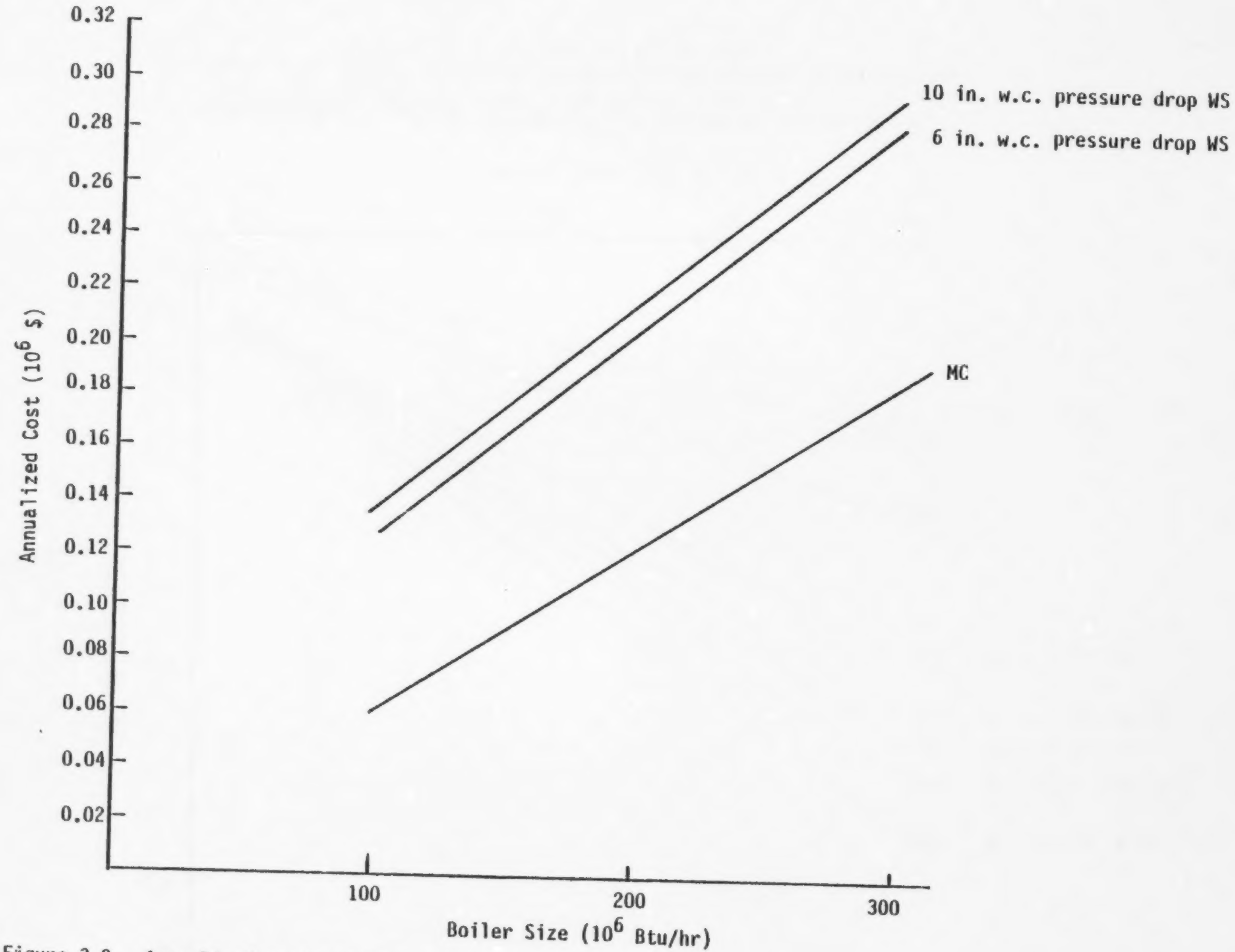


Figure 3-9. Annualized costs of PM controls applied to bagasse-fired boilers as a function of boiler size.

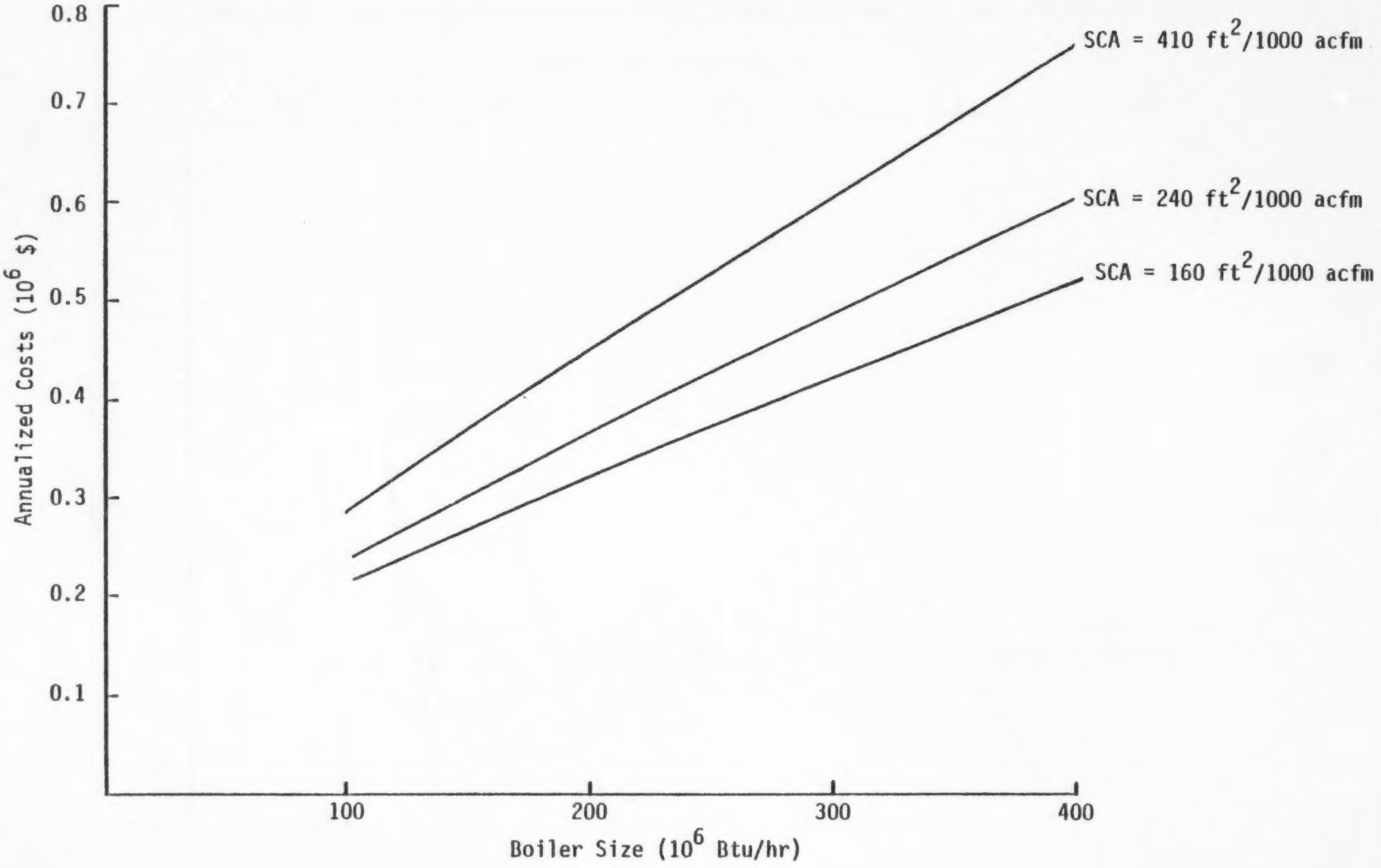


Figure 3-10. Annualized costs of ESP's applied to MSW-fired boilers as a function of boiler size.

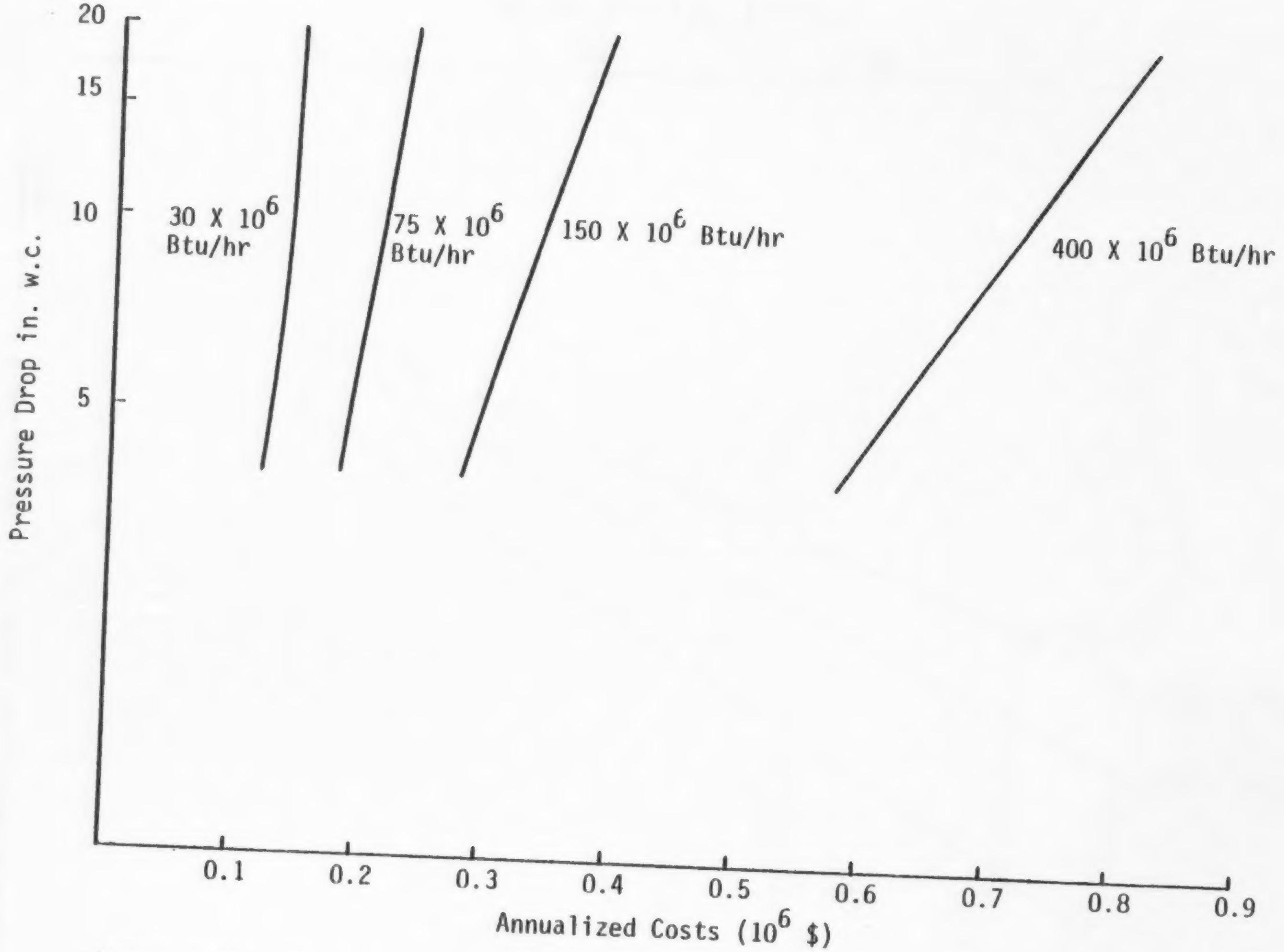


Figure 3-11. Wet scrubber annualized costs versus pressure drop for four boiler sizes.

4.0 OTHER FUEL CASES

This chapter presents particulate matter (PM) control system costs for some individual fuel cases not covered in the general model boiler categories. These costs are compared to the related model boiler costs shown in Chapter 3. The cases cover salt-laden wood fuel, wood/fossil fuel mixtures, RDF, and solid waste/fossil fuel mixtures.

4.1 SALT-LADEN WOOD FIRED BOILERS

The cost impacts of PM controls for boilers firing salt-laden wood (SLW) are examined for a 44 MW (150 x 10^6 Btu/hr) boiler size. The boiler design specifications which would differ for a boiler firing SLW as compared to wood are given in Table 4.1-1.

The PM control system for this model boiler consists of a fabric filter (FF) with an upstream mechanical collector (MC) instead of the mechanical collector/wet scrubber system used with wood firing. As shown in Table 4.1-1, boilers firing SLW have higher uncontrolled emissions than boilers firing other wood fuels (see Table 2.1-2). In addition, SLW produces a particulate with a smaller particle size than wood firing. Fabric filters are more effective than wet scrubbers on the higher loadings and smaller particle sizes found in SLW emissions. Also, the particulate from SLW firing poses a smaller fire threat than the particulate from wood firing due to the quenching effect of the salt.[1] The control system design specifications for the SLW-fired boiler case are given in Table 4.1-2.

Uncontrolled PM emissions for the SLW model boiler are 2590 ng/J (6.03 lb/10^6 Btu). The MC/FF control system shown can reduce emissions to 21.5 ng/J (0.05 lb/10^6 Btu). This control level is the only level shown because it is easily achievable by the design of fabric filter systems presently in operation on wood-fired boilers.

4.1.1 Capital Costs of a SLW-Fired Boiler PM Control System

The baghouse capital costs are estimated from a correlation based on data from GARD[2] and Wheelabrator-Frye.[3] The baghouse cost correlation estimates

TABLE 4.1-1. UNCONTROLLED SLW-FIRED BOILER DESIGN SPECIFICATIONS[g]

Thermal Input, MW (10^6 Btu/hr)	44.0 (150)
Fuel[a]	SLW
Fuel rate, kg/s (ton/hr)	4.18 (16.6)
Analysis	
% sulfur	0.02
% ash	1.49[b]
Flue gas constituents,[c] kg/hr (lb/hr)	
Fly ash (before mechanical collector)	411 (905)[d]
(after mechanical collector)[e]	142 (314)[d]
SO_2	-
NO_x	17.0 (37.5)
Ash from sand classifier,[f] kg/hr (lb/hr)	147 (325)

[a] SLW - salt-laden wood.

[b] Salt makes up 0.5 percent of the fuel composition and is included here as ash.

[c] Uncontrolled emissions.

[d] It is assumed that all salt present in the fuel leaves the boiler as fly ash and that none of the salt is collected by the mechanical collector due to its small particle size.

[e] Fly ash reinjection in use.

[f] The value shown represents the difference in the amount of fly ash collected by the mechanical collector and the amount of fly ash reinjected into the boiler furnace.

[g] Other design specifications not shown here are identical to those for a 44 MW (150 x 10^6 Btu/hr) wood-fired boiler.

TABLE 4.1-2. EMISSION CONTROL SYSTEM DESIGN SPECIFICATIONS FOR SLW-FIRED MODEL BOILER

Control System	Item	Specification
Multiple cyclone	Material of construction	Carbon steel
	Tube diameter	23 cm (9 in.)
	Pressure drop	750 Pa (3 in. w.c.)
	Design PM removal efficiency	80% (for non salt particulate only - 0% for salt particulate)
Fabric Filter	Material of construction	Carbon steel (insulated)
	Cleaning method	Pluse-jet
	Design air-to-cloth ratio	2 cm/s (4 ft/m)
	Pressure drop	1.5 kPa (6 in. w.c.)
	Filter material	Teflon-coated glass felt
	Filter life	2 years
	Power demand	4 W/m^2 filter area (0.5 $hp/1000\ ft^2$)
	Fire extinguishing system	Steam
Overall System	Pressure drop	250-750 Pa (1-3 in. w.c.) plus pressure drops from individual control equipment
	Duct features	Main duct length: 20-30 m (60-100 ft). Expansion joints for duct connecting two pieces of equipment Elbows bypass ducting (including duct, tees, elbows, dampers) for fabric filters

the baghouse equipment cost from the net filter area. Net filter area is calculated as:

$$\text{Net Filter Area (ft}^2\text{)} = \text{Gas Flow (acfm)} \times \frac{1.1}{4\text{fpm}}$$

where 1.1 is a design contingency factor and 4 fpm is the design air-to-cloth ratio. The baghouse equipment cost, as a function of the net filter area, is:

$$\text{Cost (\$1000)} = 0.0908 \times (\text{Net Filter Area, ft}^2)^{0.8138}$$

Note that in this correlation, the equipment cost does not include taxes and freight, since those items are included in the installation cost factor. The installation cost factor for the baghouse equipment is 0.78.[2,4]

The cost of Teflon-coated glass felt bags is estimated as $\$1.42/\text{ft}^2$ in mid-1978 dollars. This cost estimate is an average of costs reported by Whellabrator-Frye ($\$1.53/\text{ft}^2$) and Huyglas ($\$1.89/\text{ft}^2$) indexed from mid-1980 to mid-1978. Bag costs are estimated by multiplying the unit bag cost by the net filter area.

The installation cost factor for filter bags is based on an average installation time of 15 min/bag for a four man crew.[5] With 12 ft^2 of cloth per bag, the cost of bag installation is

$$\frac{1\text{ man-hr}}{12\text{ ft}^2} \times \frac{\$14.63}{\text{man-hr}} \times 1.26 = \$1.54/\text{ft}^2$$

where 1.26 is an indirect cost factor. This is approximately equal to the cost of the filter bag, itself, so the resulting installation cost factor is estimated as 1.0 All other components of the capital cost of the MC/FF control system were estimated using the bases shown in Chapter 2.

4.1.2 Annualized Costs for a SLW-Fired Boiler PM Control System

The bases used to develop the annualized costs for a SLW-fired boiler control system are similar to those used for a wood-fired boiler and discussed in Chapter 2. Direct labor, maintenance labor, and supervision annual cost bases are the same for the wood-fired boiler control system (MC/WS) and the SLW-fired boiler control system (MC/FF). However, maintenance material costs for a MC/FF system are estimated as 0.005 (TDI + TII) plus bag replacement costs, rather than the 0.04 (TDI) basis used for MC/WS systems. Solid waste disposal costs for a MC/FF system are also reduced because this system produces a dry solid waste rather than a sludge.

4.1.3 Comparison of PM Control System Costs for Wood Versus SLW

Table 4.1-3 compares the capital and annualized PM control system costs for wood versus SLW. These costs are based on the requirement that outlet emission levels not exceed 43 ng/J (0.1 $lb/10^6$ Btu). However, the costs of control for the SLW-fired boiler are based on an actual emission level of 0.05 $lb/10^6$ Btu. This is because at the design A/C ratios commonly used on FF applied to SLW-fired boilers the actual measured emission levels are generally 0.05 $lb/10^6$ Btu or less even though the required control level may be higher.

Table 4.1-3 shows that SLW-fired boilers will typically be about 12 percent more costly to control than wood-fired boilers on an annual basis. However, uncontrolled SLW-fired boilers emit more particulate than wood-fired boilers. Therefore, the higher costs of control are reflected in a higher amount of particulate removed.

4.2 WOOD/FOSSIL FUEL MIXTURES

In most cases, wood-fired boilers are also designed to fire fossil fuels. Fossil fuels are used when wood fuel is unavailable, the wood feed system is inoperative, or additional heat input is required to meet peak steam demands. The types of fossil fuels used are oil, natural gas, and coal. In the case of natural gas and oil, uncontrolled emissions on a heat input basis are significantly reduced when these fuels are combusted with wood. Therefore, when gas and oil are fired with wood fuel, PM emissions should be no more difficult to control than emissions from wood alone. However, when coal is fired with wood, significant amounts of particulate matter can be emitted from coal combustion. Therefore, the remainder of this section will focus on the control of PM emissions from wood/coal mixtures.

The control system which will be discussed in this section consists of a mechanical collector followed by an electrostatic precipitator. This is the type of control system commonly used on new wood/coal-fired boilers. For boilers firing fuel mixtures the ESP must potentially be designed to control PM emissions from either fuel fired alone, or both fuels when fired

TABLE 4.1-3. COMPARISON OF THE PM CONTROL SYSTEM COSTS FOR SLW VERSUS WOOD FOR A 44 MW (150 x 10^6 Btu) BOILER SIZE

Fuel	Control System	Emission Level lb/10^6 Btu	Control System Cost - 10^3 $ Capital	Control System Cost - 10^3 $ Annualized
SLW	MC/FF	0.05	1368	398
Wood	MC/WS	0.10	936	352

in combination. However, according to equipment vendors, electrostatic precipitators used in multiple fuel applications are sized based on the collection area required to reduce emissions to the desired level for the most difficult control case for either fuel fired alone. Mixed fuel emissions will be no more difficult to precipitate than the emissions from either fuel fired alone.[6,7] Therefore, the size of the ESP required to meet a specific emission level for wood/coal-fired boilers is based on the size required for either 100 percent wood or 100 percent coal firing (whichever is larger). Table 4.2-1 shows the SCA's for ESP applied to wood and coal-fired boilers based on an emission level of 43 ng/J (0.1 $lb/10^6$ Btu) at the ESP outlet. As shown in this table, wood firing requires an SCA of 250 ft^2/1000 acfm whereas coal firing requires a smaller SCA for either high or low sulfur coal. Therefore, an ESP designed to meet 43 ng/J (0.1 $lb/10^6$ Btu) when firing wood will be able to achieve this emission level, or less, when firing either high or low sulfur coals, or wood/coal mixtures.

Table 4.2-2 shows comparison of the capital and annualized costs for a MC/ESP control system capable of achieving an emission level of 43 ng/J (0.1 $lb/10^6$ Btu) and the capital and annualized costs of a MC/WS system designed to achieve the same emission level. The bases used to calculate costs of the MC/ESP system are the same as discussed in Chapter 2 for ESPs applied to MSW-fired boilers, except the capital costs are based on an SCA of 250 ft^2/1000 acfm, and the costs of the same type of mechanical collector and sand classifier systems used in the MC/WS control system are included. As shown in Table 4.2-2, the annualized cost of PM emission control for boilers firing wood/coal is basically the same as the cost for wood-fired boilers controlled with MC/WS systems.

4.3 COSTS OF PM CONTROLS FOR RDF-FIRED BOILERS

No model boiler was evaluated for RDF-fired boilers. However, emission test data from one site firing 100 percent RDF indicated that similarly sized ESPs applied to RDF firing will achieve the same emission levels as ESPs applied to MSW-fired boilers. Therefore, the costs of PM control for

TABLE 4.2-1. SCA'S REQUIRED TO ACHIEVE ESP OUTLET EMISSION LEVELS OF 43 NG/J (0.1 LB/10^6 BTU)

Fuel[d]	ESP Efficiency Required[a]	SCA ft^2/1000 acfm
Wood	90	250[c]
HSC	91	100[b]
LSC	86	185[b]

[a] Based on uncontrolled emission levels for spreader stoker boilers and the assumption that the mechanical collector precleaner is 80 percent efficient when firing either fuel.[8,9]

[b] Reference 10.

[c] Reference 11.

[d] HSC - high sulfur coal.
LSC - low sulfur coal.

TABLE 4.2-2. CAPITAL AND ANNUALIZED PM CONTROL COSTS FOR 44 MW (150×10^6) WOOD/COAL FIRED BOILER

Fuel	Emission Level ng/J (lb/10^6 Btu)	PM Emission Control System Costs Capital Costs ($1000)	 Annualized Costs ($1000/yr)
Wood/Coal	43 (0.10)	1308	349
Wood[a]	43 (0.10)	936	352

[a] Interpolated results from Tables 3-1 and 3-4.

RDF-fired boilers would be approximately the same as the costs of PM control for the MSW-fired boilers shown in Chapter 3.

4.4 SOLID WASTE/FOSSIL FUEL MIXTURES

As discussed in Section 4.2, PM control systems for boilers firing fuel mixtures and using ESP's for PM control are sized based on the fuel which is most difficult to control when it is fired alone. Boilers firing solid waste (RDF or MSW) may also fire the same types of fossil fuels used with wood fired boilers. For these boilers, as with wood, the most difficult case to control will be when firing 100 percent fossil fuels. Therefore, the cost of PM control for boilers designed to fire solid waste/fossil fuel mixtures will be no more expensive than the cost for the model boilers firing 100 percent solid waste shown in Chapter 3.

4.5 REFERENCES

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APPENDIX A

DETAILED LINE BY LINE COSTS

Appendix A presents the detailed line-by-line costs for uncontrolled model boilers and PM control systems. Separate values are shown for the equipment cost and the installation cost. The factors used to calculate the installation cost are shown in Table 2.1-6 as a function of equipment cost. Bases used to calculate other capital cost components are shown in Table 2.1-1.

Model Boiler No.	1	2	3	4	13	14	15
Fuel Type / Capacity (10^6 Btu/hr)	Wood/30	Wood/75	Wood/150	Wood/400	MSW/150	MSW/400	Bagasse/200
CAPITAL COSTS (10^3 $)							
TOTAL DIRECT AND INDIRECT INVESTMENT COSTS (TDI + TII)							
CONTINGENCIES							
TOTAL TURNKEY COSTS (TTC)(TDI + TII + CONTINGENCIES)	1700	3500	5900	13,000	16,300	34,700	5300
LAND	1	2	2	2	2	2	2
WORKING CAPITAL	101	163	225	461	223	571	144
TOTAL CAPITAL COSTS (TTC + LAND + WORKING CAPITAL)	1800	3660	6130	13,500	16,500	35,300	5450
ANNUAL COSTS (10^3 $)							
DIRECT OPERATING COSTS							
Operating Labor	157.9	236.9	342.2	710.7	342.2	710.3	223.7
Supervision	68.5	137.0	137.0	205.4	137.0	205.4	68.5
Maintenance Labor	64.1	96.2	128.1	384.3	128.1	384.3	96.1
Maintenance Materials	80.0	125	200	340	65.0	170	90.0
Electricity	30.5	50.0	82.4	172.8	69.0	183	90.0
Chemicals					42.0	112	
Process Water					5.0	14	
Fuel					7.2	20	
Solid Waste Disposal	2.3	5.8	11.7	31.1	96.1	484.8	6.3
TOTAL DIRECT OPERATING COSTS	403.3	650.9	901.4	1844	892	2284	575
INDIRECT OPERATING COSTS							
Payroll Overhead (30% of operating labor + supervision)	67.9	112.2	143.8	274.8	81.4	274.8	87.7
Plant Overhead (26% of total labor + main. matls.)	96.3	154.7	209.9	426.5	174.8	382.3	124.3
TOTAL INDIRECT OPERATING COSTS	164.2	266.9	353.7	701.3	256.2	657.1	212.0
TOTAL DIRECT AND INDIRECT OPERATING COSTS	567.5	917.8	1255	2545	1148	2941	787
CAPITAL CHARGES							
G&A, Taxes, and Insurance (4% of Total Capital Costs)	72.0	147	245	540	660	1410	218
Interest on Working Capital	10.1	16	23	46	22	57	14
Capital Recovery	236.7	481.3	806.1	1775.2	2169.8	4642.0	716.7
TOTAL CAPITAL CHARGES	318.8	644.3	1074.1	2361.2	2851.8	6109.0	948.7
TOTAL ANNUALIZED COSTS	886.3	1562.1	2329.1	4906.2	3999.8	9050	1735.7
WASTE DISPOSAL CREDIT (MSW only)	—	—	—	—	(1914)	(5097)	—

√2085.8 √3953

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 30
Emission Control System / Emission Rate (lb/10^6 Btu)	MC / 0.60

Comments: ______________________

Capital Costs (10^3 \$)

Direct Investment Costs	Equip	Instal.		
Multiclone	8.0	6.2		
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	3.2	3.8		
Solids Separation				
Ducting	3.7	5.9		
Ash Removal	3.0	1.0		
Sand Classification	7.3	9.7		
Subtotal	25.2	26.6	51.8	
Utilities and Services			3.1	
Total Direct Investment Costs (TDI)			▨	54.9
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			17.6	
Performance tests (greater of 1% of TDI or \$ 3000)			3.0	
Total Indirect investment Costs (TII)			-	20.6
Total Direct and Indirect Investment Costs (TDI + TII)				75.5
Total Turnkey Costs (TTC = TDI + TII + Contingencies [30% of TDI + TII])				90.6
Land (0.00084 TTC)				0.1
Working Capital (25 percent of Total Direct Operating Costs)				5.5
Total Capital Costs (TTC + Land + Working Capital)				96.2

Annualized Costs (10^3 \$)

Direct Operating Costs		Subtotals
Direct Labor	6.7	
Supervision	1.0	7.7
Maintence Labor	7.5	
Maintance Materials	0.4	15.6
Electricity	2.5	
Waste Disposal	▨	
Solids 75.7 lb/hr	4.0	
Sludge - lb/hr with - % solids content	-	
Total direct Operating Costs (TDOC)	▨	22.1
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	2.3	
Plant Overhead (26 percent of total labor + maintence materials	4.1	
Total Indirect Operating Costs (TIOC)	-	6.4
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	3.8	
Interest on working Capital (10 percent)	0.6	
Capital Recovery (15 year equipment life, 10 percent interest)	12.7	
Total Capital Charges	▨	17.1
Total Annualized Costs	▨	45.6

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Date	7/6/82
Fuel Type / Boiler capacity (10^6 Btu/hr)	Wood / 50
Emission Control System / Emission Rate (lb/10^6 Btu)	[illegible] / 0.[illegible]

Comments : ____________________

Capital Costs (10^3 \$)

Direct Investment Costs	Equip	Install.		
Multiclone	16.0	12.4		
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubbers				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	5.6	6.6		
Solids Separation				
Ducting	6.0	9.6		
Ash Removal	3.0	1.0		
Sand Classification	7.3	9.7		
Subtotal	37.9	39.3	77.2	
Utilities and Services			4.6	
Total Direct Investment Costs (TDI)				81.8
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			26.2	
Performance tests (greater of 1% of TDI or \$ 3000)			3.0	
Total Indirect investment Costs (TII)			-	29.2
Total Direct and Indirect Investment Costs (TDI + TII)				111.0
Total Turnkey Costs [TTC = TDI + TII + Contingencies [30% of TDI + TII])				133.2
Land (0.00084 TTC)				0.1
Working Capital (25 percent of Total Direct Operating Costs)				7.8
Total Capital Costs (TCC) = (TTC + Land + Working Capital)				141.1

Annualized Costs (10^3 \$)

Direct Operating Costs		Subtotals
Direct Labor	10.0	
Supervision	1.5	11.5
Maintence Labor	11.2	
Maintence Materials	0.6	23.3
Electricity	3.8	
Waste Disposal		
Solids 31.7 lb/hr	4.3	
Sludge – lb/hr with – % solids content	-	
Total direct Operating Costs (TDOC)		31.4
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	3.4	
Plant Overhead (26 percent of total labor + maintence materials	6.1	
Total Indirect Operating Costs (TIOC)	-	9.5
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	5.6	
Interest on working Capital (10 percent)	0.8	
Capital Recovery (15 year equipment life, 10 percent interest)	18.6	
Total Capital Charges		25.0
Total Annualized Costs		65.9

Date	3-31-82	
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 30	
Emission Control System / Emission Rate (lb/10^6 Btu)	MC, WS / 0.30	4" DP WS

Comments: ____________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip 8.0	Install. 6.2		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	9.6	6.5		
- scrubber auxiliaries	9.2	10.1		
EGB				
Fan and Motor	7.2	8.5		
Solids Separation	29.8	44.7		
Ducting	6.4	10.1		
Ash Removal	3.0	1.0		
Sand Classification	7.3	9.7		
Subtotal	80.5	96.8	177.3	
Utilities and Services			10.6	
Total Direct Investment Costs (TDI)			▨	187.9
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			60.1	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect Investment Costs (TII)			-	63.1
Total Direct and Indirect Investment Costs (TDI + TII)				251.0
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				301.2
Land (0.00084 TTC)				0.3
Working Capital (25 percent of Total Direct Operating Costs)				12.4
Total Capital Costs (TTC + Land + Working Capital)				313.9

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	13.3	
Supervision	2.0	15.3
Maintence Labor	14.9	
Maintance Materials	7.5	37.7
Electricity	4.8	
Waste Disposal	▨	
Solids 64.4 lb/hr	3.4	
Sludge 68 lb/hr with 30 % solids content	3.6	
Total direct Operating Costs (TDOC)	▨	49.5
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	4.6	
Plant Overhead (26 percent of total labor + maintence materials	9.8	
Total Indirect Operating Costs (TIOC)	-	14.4
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	12.6	
Interest on Working Capital (10 percent)	1.2	
Capital Recovery (15 year equipment life, 10 percent interest)	41.3	
Total Capital Charges	▨	55.1
Total Annualized Costs	▨	119.0

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 30
Emission Control System / Emission Rate (lb/10^6 Btu)	MC,WS / 0.15

9" DPWS

Comments : ______________________________

Capital Costs (10^3 \$)

Direct Investment Costs	Equip	Install		
Multiclone	8.0	6.2		
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	18.4	12.5		
- scrubber auxiliaries	11.2	11.9		
EGB				
Fan and Motor	10.1	11.9		
Solids Separation	31.8	47.7		
Ducting	6.4	10.1		
Ash Removal	3.0	1.0		
Sand Classification	7.3	9.7		
Subtotal	96.2	111.0	207.2	
Utilities and Services			12.4	
Total Direct Investment Costs (TDI)			▨	219.6
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			70.3	
Performance tests (greater of 1% of TDI or \$3000)			3.0	
Total Indirect Investment Costs (TII)			-	73.3
Total Direct and Indirect Investment Costs (TDI + TII)				292.9
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI+TII])				351.5
Land (0.00084 TTC)				- 0.3
Working Capital (25 percent of Total Direct Operating Costs)				13.9
Total Capital Costs (TTC + Land + Working Capital)				365.7

Annualized Costs (10^3 \$)

Direct Operating Costs		Subtotals
Direct Labor	13.3	
Supervision	2.0	15.3
Maintenance Labor	14.9	
Maintenance Materials	8.8	39.0
Electricity	8.8	
Waste Disposal	▨	
Solids 64.4 lb/hr	3.4	
Sludge 820 lb/hr with 30 % solids content	4.3	
Total direct Operating Costs (TDOC)	▨	55.5
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	4.6	
Plant Overhead (26 percent of total labor + maintenance materials	10.1	
Total Indirect Operating Costs (TIOC)	-	14.7
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	14.6	
Interest on Working Capital (10 percent)	1.4	
Capital Recovery (15 year equipment life, 10 percent interest)	48.1	
Total Capital Charges	▨	64.1
Total Annualized Costs	▨	134.3

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 30
Emission Control System / Emission Rate (lb/10^6 Btu)	MC.WS / 0.05 20"ΔP WS

Comments : ____________________

Capital Costs (10^3 $)

	Equip	Install.		
Direct Investment Costs	8.0	6.2		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	18.4	12.5	--	
- scrubber auxiliaries	11.2	11.9		
EGB				
Fan and Motor	14.7	17.3		
Solids Seperation	33.1	49.6		
Ducting	6.4	10.1		
Ash Removal	3.0	1.0		
Sand Classification	7.3	9.7		
Subtotal	102.1	118.3	220.4	
Utilities and Services			13.2	
Total Direct Investment Costs (TDI)			▨	233.6
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			74.8	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect Investment Costs (TII)			-	77.8
Total Direct and Indirect Investment Costs (TDI + TII)				311.4
Total Turn Key Costs (TTC = TDI + TII + Contingencies[20% of TDI+TII])				373.7
Land (0.00084 TTC)				0.3
Working Capital (25 percent of Total Direct Operating Costs)				15.4
Total Capital Costs (TTC + Land + Working Capital)				389.4

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor	13.3	
Supervision	2.0	15.3
Maintence Labor	14.9	
Maintence Materials	9.3	39.5
Electricity	13.8	
Waste Disposal	▨	
Solids 64.4 lb/hr	3.4	
Sludge 92.0 lb/hr with 30 % solids content	4.8	
Total direct Operating Costs (TDOC)	▨	61.5
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	4.6	
Plant Overhead (26 percent of total labor + maintence materials	10.3	
Total Indirect Operating Costs (TIOC)	—	14.9
Capital Charges	—	
G&A, Taxes and Insurance (4 percent of TCC)	15.6	
Interest on working Capital (10 percent)	1.5	
Capital Recovery (15 year equipment life, 10 percent interest)	51.2	
Total Capital Charges	▨	68.3
Total Annualized Costs	▨	144.7

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Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 75
Emission Control System / Emission Rate (lb/10^6 Btu)	MC / 0.60

Comments : ______________________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip 16.8	Instal. 12.9		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	6.5	7.7		
Solids Separation				
Ducting	6.1	9.8		
Ash Removal	3.0	1.0		
Sand Classification	9.1	12.2		
Subtotal	41.5	43.6	85.1	
Utilities and Services			5.1	
Total Direct Investment Costs (TDI)			▨	90.2
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expenses (22% of TDI)			28.8	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect Investment Costs (TII)			–	31.8
Total Direct and Indirect Investment Costs (TDI + TII)				122.0
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				146.4
Land (0.00084 TTC)				0.1
Working Capital (25 percent of Total Direct Operating Costs)				8.6
Total Capital Costs (TTC + Land + Working Capital)				155.1

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	9.0	
Supervision	1.4	10.4
Maintence Labor	7.7	
Maintance Materials	0.6	18.7
Electricity	5.8	
Waste Disposal	▨	
Solids 189 lb/hr	9.9	
Sludge ____ lb/hr with _____ % solids content	–	
Total direct Operating Costs (TDOC)	▨	34.4
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	3.1	
Plant Overhead (26 percent of total labor + maintenance materials	4.9	
Total Indirect Operating Costs (TIOC)	–	8.0
Capital Charges		
G+A, Taxes and Insurance (4 percent of TCC)	6.2	
Interest on Working Capital (10 percent)	0.9	
Capital Recovery (15 year equipment life, 10 percent interest)	20.4	
Total Capital Charges	▨	27.5
Total Annualized Costs	▨	69.9

Date	[illegible]
Fuel Type / Boiler Capacity (10^6 Btu/hr)	[illegible] / 75
Emission Control System / Emission Rate (10^6 Btu)	[illegible] / [illegible]

Comments: ______________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip.	Install.		
	33.6	25.8		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	[illegible]	14.9		
Solids Separation				
Ducting	9.1	14.6		
Ash Removal	2.0	1.0		
Sand Classification	2.8	1.8		
Subtotal	67.1	68.1	35.2	
Utilities and Services			8.1	
Total Direct Investment Costs (TDI)				143.3
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			45.9	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect Investment Costs (TII)				48.9
Total Direct and Indirect Investment Costs (TDI + TII)				192.2
Total Turnkey Costs [TTC = TDI + TII + Contingencies (20% of TDI + TII)]				230.6
Land (0.00084 TTC)				0.2
Working Capital (25 percent of Total Direct Operating Costs)				12.0
Total Capital Costs (TCC) = (TTC + Land + Working Capital)				242.8

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	13.6	
Supervision	2.0	15.6
Maintenance Labor	1.6	
Maintenance Materials	1.0	28.2
Electricity	2.1	
Waste Disposal		
Solids 204 lb/hr	10.7	
Sludge ____ lb/hr with ____ % solids content	-	
Total Direct Operating Costs (TDOC)		48.0
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	4.7	
Plant Overhead (26 percent of total labor + maintenance materials)	7.3	
Total Indirect Operating Costs (TIOC)		12.0
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	9.7	
Interest on Working Capital (10 percent)	1.2	
Capital Recovery (____ year equipment life, ____ percent interest)	31.9	
Total Capital Charges		43.3
Total Annualized Costs		102.3

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 75
Emission Control System / Emission Rate (lb/10^6 Btu)	MC, WS / 0.30

4'DP ~S

Comments: ____________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip 16.8	Install. 12.9		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber			-	
- scrubber	19.1	13.0		
- scrubber auxiliaries	13.1	13.9		
EGB				
Fan and Motor	16.7	19.7		
Solids Separation	41.0	61.5		
Ducting	9.6	15.4		
Ash Removal	3.0	1.0		
Sand Classification	8.8	11.8		
Subtotal	128.1	149.2	277.3	
Utilities and Services			0.6	
Total Direct Investment Costs (TDI)			▨	293.9
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			94.0	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect Investment Costs (TII)			-	97.0
Total Direct and Indirect Investment Costs (TDI + TII)				390.9
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				469.1
Land (0.00084 TTC)				0.4
Working Capital (25 percent of Total Direct Operating Costs)				19.2
Total Capital Costs (TTC + Land + Working Capital)				488.7

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor	19.1	
Supervision	2.7	20.3
Maintence Labor	15.4	
Maintance Materals	11.8	48.0
Electricity 8401 kw	11.4	
Waste Disposal	▨	
Solids 161 lb/hr	8.5	
Sludge 169 lb/hr with 30 % solids content	8.9	
Total direct Operating Costs (TDOC)	▨	76.3
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	6.2	
Plant Overhead (26 percent of total labor + maintenance materials	12.5	
Total Indirect Operating Costs (TIOC)	-	18.7
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	19.5	
Interest on Working Capital (10 percent)	1.9	
Capital Recovery (15 year equipment life, 10 percent interest)	64.3	
Total Capital Charges	▨	85.7
Total Annualized Costs	▨	181.2

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 75
Emission Control System / Emission Rate (lb/10^6 Btu)	MC WS / 0.15

9" ΔP WS

Comments: ______

Capital Costs (10^3 $)

Direct Investment Costs	Equip 16.8	Install 12.9		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	26.9	18.3		
- scrubber auxiliaries	18.0	16.1		
EGB				
Fan and Motor	23.5	27.7		
Solids Separation	43.8	65.7		
Ducting	9.6	15.4		
Ash Removal	3.0	1.0		
Sand Classification	8.8	11.8		
Subtotal	150.4	168.9	319.3	
Utilities and Services			19.2	
Total Direct Investment Costs (TDI)				338.5
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			108.3	
Performance tests (greater of 1% of TDI or $ 3000)			3.4	
Total Indirect Investment Costs (TII)			-	111.7
Total Direct and Indirect Investment Costs (TDI + TII)				450.2
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				540.2
Land (0.00084 TTC)				0.5
Working Capital (25 percent of Total Direct Operating Costs)				22.6
Total Capital Costs (TTC + Land + Working Capital)				563.3

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	18.1	
Supervision	2.7	20.8
Maintenance Labor	15.4	
Maintenance Materials	13.5	49.7
Electricity	21.5	
Waste Disposal		
Solids 161 lb/hr	8.5	
Sludge 205 lb/hr with 30 % solids content	10.8	
Total Direct Operating Costs (TDOC)		90.5
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	6.2	
Plant Overhead (26 percent of total labor + maintenance materials	12.9	
Total Indirect Operating Costs (TIOC)		19.1
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	22.5	
Interest on Working Capital (10 percent)	2.3	
Capital Recovery (15 year equipment life, 10 percent interest)	74.1	
Total Capital Charges		98.9
Total Annualized Costs		208.5

Date	3-31-82
Fuel Type / Boiler capacity (10⁶ Btu/hr)	Wood / 75
Emission Control System / Emission Rate (lb/10⁶ Btu)	MC-WS / 0.05

20"ΔP WS

Comments: ______________________________

Capital Costs (10³ $)

Direct Investment Costs	Equip 16.8	Install 12.9		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	26.9	18.3		
- scrubber auxiliaries	18.0	16.1		
EGB				
Fan and Motor	35.0	41.2		
Solids Separation	45.6	68.4		
Ducting	9.6	15.4		
Ash Removal	3.0	1.0		
Sand Classification	8.8	11.8		
Subtotal	163.7	185.1	348.8	
Utilities and Services			20.9	
Total Direct Investment Costs (TDI)				369.7
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expenses (22% of TDI)			118.3	
Performance tests (greater of 1% of TDI or $3000)			3.7	
Total Indirect Investment Costs (TII)			-	122.0
Total Direct and Indirect Investment Costs (TDI + TII)				491.7
Total Turnkey Costs (TTC = TDI + TII + Contingencies [30% of TDI+TII])				590.0
Land (0.00084 TTC)				0.5
Working Capital (25 percent of Total Direct Operating Costs)				26.4
Total Capital Costs (TTC + Land + Working Capital)				616.9

Annualized Costs (10³ $)

Direct Operating Costs		Subtotals
Direct Labor	18.1	
Supervision	2.7	20.8
Maintenance Labor	15.4	
Maintenance Materials	14.8	51.0
Electricity	34.2	
Waste Disposal		
Solids 161 lb/hr	8.5	
Sludge 230 lb/hr with 30 % solids content	12.1	
Total direct Operating Costs (TDOC)		105.8
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	6.2	
Plant Overhead (26 percent of total labor + maintenance materials	13.3	
Total Indirect Operating Costs (TIOC)	-	19.5
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	24.7	
Interest on Working Capital (10 percent)	2.6	
Capital Recovery (15 year equipment life, 10 percent interest)	81.1	
Total Capital Charges		108.4
Total Annualized Costs		233.7

Date	3-31-82
Fuel Type / Boiler capacity (10^6 Btu/hr)	Wood / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	MC / 0.60

Comments :

Capital Costs (10^3 $)

	Equip	Install.		
Direct Investment Costs	30.5	25.3		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	13.6	16.0		
Solids Separation				
Ducting	9.5	15.2		
Ash Removal	15.4	15.4		
Sand Classification	13.9	18.7		
Subtotal	82.9	90.6	173.5	
Utilities and Services			10.4	
Total Direct Investment Costs (TDI)				183.9
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			58.9	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect Investment Costs (TII)			-	61.9
Total Direct and Indirect Investment Costs (TDI + TII)				245.8
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				294.9
Land (0.00084 TTC)				0.2
Working Capital (25 percent of Total Direct Operating Costs)				14.3
Total Capital Costs (TTC + Land + Working Capital)				309.4

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor	13.0	
Supervision	2.0	15.0
Maintenance Labor	8.6	
Maintenance Materials	1.2	24.8
Electricity	12.6	
Waste Disposal		
Solids 378 lb/hr	19.9	
Sludge - lb/hr with - % solids content	-	
Total direct Operating Costs (TDOC)		57.3
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	4.5	
Plant Overhead (26 percent of total labor + maintenance materials	6.4	
Total Indirect Operating Costs (TIOC)	-	10.9
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	12.4	
Interest on Working Capital (10 percent)	1.4	
Capital Recovery (15 year equipment life, 10 percent interest)	40.7	
Total Capital Charges		54.5
Total Annualized Costs		122.7

Date	6/7/82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	[illegible] / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	[illegible] / 0.4

Comments: ______________________________

Capital Costs (10^3 $)

	Equip	Install		
Direct Investment Costs	61.0	50.6		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	22.0	26.0		
Solids Separation	-	-		
Ducting	13.3	21.3		
Ash Removal	15.2	15.2		
Sand Classification	10.7	24.3		
Subtotal	122.2	137.4	259.6	
Utilities and Services			15.0	
Total Direct Investment Costs (TDI)				274.6
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			84.7	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect Investment Costs (TII)			87.7	87.7
Total Direct and Indirect Investment Costs (TDI + TII)				362.3
Total Turnkey Costs [TTC = TDI + TII + Contingencies (20% of TDI + TII)]				423.3
Land (0.00034 TTC)				0.1
Working Capital (25 percent of Total Direct Operating Costs)				19.1
Total Capital Costs (TCC) = (TTC + Land + Working Capital)				442.5

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor (1.5 × [illegible])	19.5	
Supervision ([illegible])	2.9	22.4
Maintenance Labor ([illegible])	12.4	
Maintenance Materials ([illegible] TDI + TII)	7.5	[illegible]
Electricity	[illegible]	
Waste Disposal		
Solids 408 t/hr	21.4	
Sludge ______ t/hr with ______ % solids content	-	
Total Direct Operating Costs (TDOC)		76.5
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	6.7	
Plant Overhead (26 percent of total labor + maintenance materials	9.6	
Total Indirect Operating Costs (TIOC)		16.3
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	17.7	
Interest on Working Capital (10 percent)	1.9	
Capital Recovery (15 year equipment life, 12 percent interest)	58.2	
Total Capital Charges		77.8
Total Annualized Costs		170.6

Date ___ ___	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr) ___	Wood / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	MCWS / 0.30

4'DP WS

Comments: ______________________________

Capital Costs (10^3 \$)

	Equip	Install		
Direct Investment Costs	30.5	25.3		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	32.1	21.8		
- scrubber auxiliaries	17.9	18.7		
EGB				
Fan and Motor	27.6	32.6		
Solids Separation	52.3	78.5		
Ducting	13.8	22.1		
Ash Removal	12.9	12.9		
Sand Classification	10.7	14.3		
Subtotal	197.8	226.2	424.0	
Utilities and Services			25.4	
Total Direct Investment Costs (TDI)				449.4
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			143.8	
Performance tests (greater of 1% of TDI or \$3000)			4.5.	
Total Indirect Investment Costs (TII)			-	148.3
Total Direct and Indirect Investment Costs (TDI + TII)				597.7
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				717.2
Land (0.00084 TTC)				0.6
Working Capital (25 percent of Total Direct Operating Costs)				30.6
Total Capital Costs (TTC + Land + Working Capital)				748.4

Annualized Costs (10^3 \$)

		Subtotals
Direct Operating Costs		
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	18.0	65.1
Electricity	22.6	
Waste Disposal		
Solids 322 lb/hr	16.9	
Sludge 338 lb/hr with 30 % solids content	17.8	
Total direct Operating Costs (TDOC)		122.4
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials	16.9	
Total Indirect Operating Costs (TIOC)	–	25.9
Capital Charges	–	
G&A, Taxes and Insurance (4 percent of TCC)	29.9	
Interest on Working Capital (10 percent)	3.1	
Capital Recovery (15 year equipment life, 10 percent interest)	98.4	
Total Capital Charges		131.4
Total Annualized Costs		279.7

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	MCWS / 0.15 9"DP WS

Comments: ____________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip 30.5	Install 25.3		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	40.1	27.3		
- scrubber auxiliaries	24.8	22.7		
EGB				
Fan and Motor	46.2	54.5		
Solids Separation	55.9	83.8		
Ducting	13.8	22.1		
Ash Removal	12.9	12.9		
Sand Classification	10.7	14.3		
Subtotal	234.9	262.9	497.8	
Utilities and Services			29.9	
Total Direct Investment Costs (TDI)				527.7
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			168.9	
Performance tests (greater of 1% of TDI or $ 3000)			5.3	
Total Indirect investment Costs (TII)			-	174.2
Total Direct and Indirect Investment Costs (TDI + TII)				701.9
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				842.3
Land (0.00084 TTC)				0.7
Working Capital (25 percent of Total Direct Operating Costs)				37.3
Total Capital Costs (TTC + Land + Working Capital)				880.3

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	21.1	68.2
Electricity	42.6	
Waste Disposal		
Solids 322 lb/hr	16.9	
Sludge 410 lb/hr with 30 % solids content	21.5	
Total direct Operating Costs (TDOC)		149.2
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials	17.7	
Total Indirect Operating Costs (TIOC)	-	26.7
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	35.2	
Interest on Working Capital (10 percent)	3.7	
Capital Recovery (15 year equipment life, 10 percent interest)	115.8	
Total Capital Charges		154.7
Total Annualized Costs		330.6

Date ___ ___	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr) ___	Wood / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	MCWS / 0.05

20" ΔP WS

Comments: ______________________________

Capital Costs (10^3 $)

	Equip	Install		
Direct Investment Costs	30.5	25.3		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	62.0	42.2		
- scrubber auxiliaries	24.8	22.7		
EGB				
Fan and Motor	67.6	79.7		
Solids Separation	58.2	87.3		
Ducting	13.8	22.1		
Ash Removal	12.9	12.9		
Sand Classification	10.7	14.3		
Subtotal	280.5	306.5	587.0	
Utilities and Services			35.2	
Total Direct Investment Costs (TDI)			▨	622.2
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (32% of TDI)			199.1	
Performance tests (greater of 1% of TDI or $ 3000)			6.2	
Total Indirect Investment Costs (TII)			-	205.3
Total Direct and Indirect Investment Costs (TDI + TII)				827.5
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				993.0
Land (0.00084 TTC)				0.8
Working Capital (25 percent of Total Direct Operating Costs)				45.2
Total Capital Costs (TTC + Land + Working Capital)				1039.0

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	24.9	72.0
Electricity	67.8	
Waste Disposal	▨	
Solids 322 lb/hr	16.9	
Sludge 460 lb/hr with 30 % solids content	24.2	
Total direct Operating Costs (TDOC)	▨	180.9
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials	18.7	
Total Indirect Operating Costs (TIOC)	-	27.7
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	41.6	
Interest on working Capital (10 percent)	4.5	
Capital Recovery (15 year equipment life, 10 percent interest)	136.6	
Total Capital Charges	▨	182.7
Total Annualized Costs	▨	391.3

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 400
Emission Control System / Emission Rate (lb/10^6 Btu)	MC / 0.63

Comments: ____________

Capital Costs (10^3 $)

	Equip	Install		
Direct Investment Costs	79.7	61.4		
Multiclone				
Baghouse - baghouse - filter bags				
ESP				
Scrubber - scrubber - scrubber auxiliaries				
EGB				
Fan and Motor	33.8	40.0		
Solids Separation				
Ducting	25.0	40.0		
Ash Removal	18.1	18.1		
Sand Classification	25.0	33.5		
Subtotal	181.6	193.0	374.6	
Utilities and Services			22.5	
Total Direct Investment Costs (TDI)			▨	397.1
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			127.1	
Performance tests (greater of 1% of TDI or $ 3000)			4.0	
Total Indirect investment Costs (TII)				131.1
Total Direct and Indirect Investment Costs (TDI + TII)				528.2
Total TurnKey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				633.8
Land (0.00084 TTC)				0.5
Working Capital (25 percent of Total Direct Operating Costs)				33.6
Total Capital Costs (TTC + Land + Working Capital)				667.9

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor	26.3	
Supervision	3.9	30.2
Maintenance Labor	15.9	
Maintenance Materials	2.6	48.7
Electricity	32.7	
Waste Disposal	▨	
Solids 1009 lb/hr	53.0	
Sludge – lb/hr with – % solids content	-	
Total direct Operating Costs (TDOC)	▨	134.4
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	9.1	
Plant Overhead (26 percent of total labor + maintenance materials	12.7	
Total Indirect Operating Costs (TIOC)	–	21.8
Capital Charges	–	
G&A, Taxes and Insurance (4 percent of TCC)	26.7	
Interest on Working Capital (10 percent)	3.4	
Capital Recovery (15 year equipment life, 10 percent interest)	87.8	
Total Capital Charges	▨	117.9
Total Annualized Costs	▨	274.1

Date	2/17/82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	[illegible] / [illegible]
Emission Control System / Emission Rate (lb/10^6 Btu)	[illegible] / 0.4

Comments: ______________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip 159.4	Install 122.8		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	53.2	62.8		
Solids Separation				
Ducting	30.5	48.8		
Ash Removal	17.7	17.7		
Sand Classification	21.4	28.7		
Subtotal	282.2	280.8	563.0	
Utilities and Services			33.8	
Total Direct Investment Costs (TDI)			[redacted]	596.8
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expenses (22% of TDI)			191.0	
Performance tests (greater of 1% of TDI or $3000)			6.0	
Total Indirect Investment Costs (TII)			197.0	197.0
Total Direct and Indirect Investment Costs (TDI + TII)				793.8
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				952.6
Land (0.00084 TTC)				0.8
Working Capital (25 percent of Total Direct Operating Costs)				44.7
Total Capital Costs (TCC) = (TTC + Land + Working Capital)				998.1

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	29.4	
Supervision	5.9	35.3
Maintenance Labor	33.8	
Maintenance Materials	4.0	73.1
Electricity	48.4	
Waste Disposal	[redacted]	
Solids 1087 lb/hr	57.2	
Sludge ______ lb/hr with ______ % solids content	-	
Total Direct Operating Costs (TDOC)	[redacted]	178.7
Indirect Operating Costs	[redacted]	
Payroll Overhead (30 percent of direct labor + supervision)	10.6	
Plant Overhead (26 percent of total labor + maintenance materials	19.0	
Total Indirect Operating Costs (TIOC)		29.6
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	39.9	
Interest on Working Capital (10 percent)	4.5	
Capital Recovery (______ year equipment life, ______ percent interest)	131.9	
Total Capital Charges	[redacted]	176.7
Total Annualized Costs	[redacted]	385.0

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Date	3-31-82
Fuel Type / Boiler Capacity (10^3 lb/hr)	Wood / 400
Emission Control System / Emission Rate (lb/10^6 Btu)	MC WS / 0.30 — 4" DPWS

Comments: ______

Capital Costs (10^3 \$)

	Equip	Install		
Direct Investment Costs	79.7	61.4		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	67.0	45.6		
- scrubber auxiliaries	28.3	27.9		
EGB				
Fan and Motor	66.2	78.1		
Solids Separation	73.5	110.3		
Ducting	30.4	48.6		
Ash Removal	15.0	15.0		
Sand Classification	21.4	28.7		
Subtotal	381.5	415.6	797.1	
Utilities and Services			47.8	
Total Direct Investment Costs (TDI)			▨	844.9
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			270.4	
Performance tests (greater of 1% of TDI or \$3000)			8.4	
Total Indirect Investment Costs (TII)			-	278.8
Total Direct and Indirect Investment Costs (TDI + TII)				1123.7
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				1348.4
Land (0.00084 TTC)				1.1
Working Capital (25 percent of Total Direct Operating Costs)				69.5
Total Capital Costs (TTC + Land + Working Capital)				1419.0

Annualized Costs (10^3 \$)

		Subtotals
Direct Operating Costs		
Direct Labor	52.6	
Supervision	7.9	60.5
Maintenance Labor	31.8	
Maintenance Materials	33.8	126.1
Electricity	59.8	
Waste Disposal	▨	
Solids 859 lb/hr	45.1	
Sludge 893 lb/hr with 30 % solids content	46.9	
Total Direct Operating Costs (TDOC)	▨	277.9
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	18.2	
Plant Overhead (26 percent of total labor + maintenance materials	32.8	
Total Indirect Operating Costs (TIOC)	-	51.0
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	56.8	
Interest on Working Capital (10 percent)	7.0	
Capital Recovery (15 year equipment life, 10 percent interest)	186.6	
Total Capital Charges	▨	250.4
Total Annualized Costs	▨	579.3

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Wood / 400
Emission Control System / Emission Rate (lb/10^6 Btu)	MC WS / 0.15 9"ΔP WS

Comments: ______

Capital Costs (10^3 \$)

Direct Investment Costs	Equip 79.7	Install 61.4		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	104.0	70.7		
- scrubber auxiliaries	42.4	38.4		
EGB				
Fan and Motor	91.6	108.1		
Solids Separation	78.9	118.3		
Ducting	30.4	48.6		
Ash Removal	15.0	15.0		
Sand Classification	21.4	28.7		
Subtotal	463.4	489.2	952.6	
Utilities and Services			57.2	
Total Direct Investment Costs (TDI)			▨	1009.8
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			323.1	
Performance tests (greater of 1% of TDI or \$ 3000)			10.1	
Total Indirect Investment Costs (TII)				333.2
Total Direct and Indirect Investment Costs (TDI + TII)				1343.0
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				1611.6
Land (0.00084 TTC)				1.4
Working Capital (25 percent of Total Direct Operating Costs)				87.1
Total Capital Costs (TTC + Land + Working Capital)				1700.1

Annualized Costs (10^3 \$)

Direct Operating Costs		Subtotals
Direct Labor	52.6	
Supervision	7.9	60.5
Maintence Labor	31.8	
Maintence Materials	40.4	132.7
Electricity	113.1	
Wate Disposal	▨	
Solids 859 lb/hr	45.1	
Sludge 1093 lb/hr with 30 % solids content	57.5	
Total direct Operating Costs (TDOC)	▨	348.4
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	18.2	
Plant Overhead (26 percent of total labor + maintence materials	34.5	
Total Indirect Operating Costs (TIOC)	–	52.7
Capital Charges	–	
G&A, Taxes and Insurance (4 percent of TCC)	68.0	
Interest on working Capital (10 percent)	8.7	
Capital Recovery (____ year equipment life, ____ percent interest)	223.6	
Total Capital Charges	▨	300.3
Total Annualized Costs	▨	701.4

Date	3-31-82
Fuel Type / Boiler Capacity (10³ lb/hr)	Wood / 400
Emission Control System / Emission Rate (lb/10⁶ Btu)	MC, WS / 0.05

20" DP WS

Comments: ______________________________

Capital Costs (10³ $)

Direct Investment Costs	Equip	Install		
	79.7	61.4		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	116.6	79.3		
- scrubber auxiliaries	42.4	38.4		
EGB				
Fan and Motor	134.4	158.6		
Solids Separation	82.1	123.2		
Ducting	30.4	48.6		
Ash Removal	15.0	15.0		
Sand Classification	21.4	28.7		
Subtotal	522.0	553.2	1075.2	
Utilities and Services			64.5	
Total Direct Investment Costs (TDI)				1139.7
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			364.7	
Performance tests (greater of 1% of TDI or $ 3000)			11.4	
Total Indirect Investment Costs (TII)			-	376.1
Total Direct and Indirect Investment Costs (TDI + TII)				1515.8
Total Turnkey Costs (TTC = TDI + TII + Contingencies [30% of TDI + TII])				1819.0
Land (0.00084 TTC)				1.5
Working Capital (25 percent of Total Direct Operating Costs)				106.9
Total Capital Costs (TTC + Land + Working Capital)				1927.4

Annualized Costs (10³ $)

Direct Operating Costs		Subtotals
Direct Labor	52.6	
Supervision	7.9	60.5
Maintence Labor	31.8	
Maintence Materials	45.6	137.9
Electricity	180.0	
Waste Disposal		
Solids 859 lb/hr	45.1	
Sludge 1227 lb/hr with 30 % solids content	64.5	
Total direct Operating Costs (TDOC)		427.5
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	18.2	
Plant Overhead (26 percent of total labor + maintenance materials	35.9	
Total Indirect Operating Costs (TIOC)	-	54.1
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	77.1	
Interest on Working Capital (10 percent)	10.7	
Capital Recovery (___ year equipment life, ___ percent interest)	253.5	
Total Capital Charges		341.3
Total Annualized Costs		822.9

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Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	MSW / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	ESP / 0.17

Comments: —

Capital Costs (10^3 $)

Direct Investment Costs	Equip	Install		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP	243.0	243.0		
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	19.2	22.7		
Solids Separation				
Ducting	29.7	47.5		
Ash Removal	1.4	1.4		
Sand Classification				
Subtotal	293.3	314.6	607.9	
Utilities and Services			36.5	
Total Direct Investment Costs (TDI)				644.4
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			206.2	
Performance tests (greater of 1% of TDI or $ 3000)			6.4	
Total Indirect Investment Costs (TII)			-	212.6
Total Direct and Indirect Investment Costs (TDI + TII)				857.0
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI+TII])				1028.4
Land (0.00084 TTC)				0.9
Working Capital (25 percent of Total Direct Operating Costs)				20.4
Total Capital Costs (TTC + Land + Working Capital)				1049.7

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	4.3	51.4
Electricity	14.2	
Waste Disposal		
Solids 480 lb/hr	15.8	
Sludge - lb/hr with - % solids content	-	
Total direct Operating Costs (TDOC)		81.4
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials	13.4	
Total Indirect Operating Costs (TIOC)	-	22.4
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	42.0	
Interest on Working Capital (10 percent)	2.0	
Capital Recovery (15 year equipment life, 10 percent interest)	138.0	
Total Capital Charges		182.0
Total Annualized Costs		285.8

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	MSW / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	ESP / 0.10

Comments : ____________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip	Install		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP	268.1	268.1		
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	19.2	22.7		
Solids Separation				
Ducting	29.7	47.5		
Ash Removal	1.4	1.4		
Sand Classification				
Subtotal	318.4	339.7	658.1	
Utilities and Services			39.5	
Total Direct Investment Costs (TDI)				697.6
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expenses (22% of TDI)			223.2	
Performance tests (greater of 1% of TDI or $ 3000)			7.0	
Total Indirect Investment Costs (TII)			-	230.2
Total Direct and Indirect Investment Costs (TDI + TII)				927.8
Total Turnkey Costs (TTC = TDI + TII + Contingencies [30% of TDI + TII])				1113.4
Land (0.00084 TTC)				0.9
Working Capital (25 percent of Total Direct Operating Costs)				21.3
Total Capital Costs (TTC + Land + Working Capital)				1135.6

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	4.6	51.7
Electricity	17.3	
Waste Disposal		
Solids 490 lb/hr	16.1	
Sludge – lb/hr with – % solids content	-	
Total direct Operating Costs (TDOC)		85.1
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials	13.4	
Total Indirect Operating Costs (TIOC)	-	22.4
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	45.4	
Interest on working Capital (10 percent)	2.1	
Capital Recovery (15 year equipment life, 10 percent interest)	149.3	
Total Capital Charges		196.8
Total Annualized Costs		304.3

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	MSW / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	ESP / 0.05

Comments : ______________________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip.	Install.		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP	336.0	336.0		
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	19.2	22.7		
Solids Separation				
Ducting	29.7	47.5		
Ash Removal	1.4	1.4		
Sand Classification				
Subtotal	386.3	407.6	793.9	
Utilities and Services			47.6	
Total Direct Investment Costs (TDI)			▨	841.5
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expenses (22% of TDI)			269.3	
Performance tests (greater of 1% of TDI or $ 3000)			8.4	
Total Indirect investment Costs (TII)			-	277.7
Total Direct and Indirect Investment Costs (TDI + TII)				1119.2
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				1343.0
Land (0.00084 TTC)				1.1
Working Capital (25 percent of Total Direct Operating Costs)				23.2
Total Capital Costs (TTC + Land + Working Capital)				1367.3

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	5.6	52.7
Electricity	23.7	
Waste Disposal	▨	
Solids 498 lb/hr	16.4	
Sludge – lb/hr with – % solids content	-	
Total direct Operating Costs (TDOC)	▨	92.8
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials)	13.7	
Total Indirect Operating Costs (TIOC)	-	22.7
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	54.7	
Interest on Working Capital (10 percent)	2.3	
Capital Recovery (____ year equipment life, ____ percent interest)	179.8	
Total Capital Charges	▨	236.8
Total Annualized Costs	▨	352.3

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	MSW / 400
Emission Control System / Emission Rate (lb/10^6 Btu)	ESP / 0.17

Comments: ____________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip	Install		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP	348.0	348.0		
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	53.1	62.7		
Solids Separation				
Ducting	62.1	99.4		
Ash Removal	1.7	1.7		
Sand Classification				
Subtotal	464.9	511.8	976.7	
Utilities and Services			58.6	
Total Direct Investment Costs (TDI)			▨	1035.3
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			331.3	
Performance tests (greater of 1% of TDI or $3000)			10.4	
Total Indirect Investment Costs (TII)			-	341.7
Total Direct and Indirect Investment Costs (TDI + TII)				1377.0
Total Turnkey Costs (TTC = TDI + TII + Contingencies [30% of TDI + TII])				1652.4
Land (0.00084 TTC)				1.4
Working Capital (25 percent of Total Direct Operating Costs)				41.8
Total Capital Costs (TTC + Land + Working Capital)				1695.0

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	52.6	
Supervision	7.9	60.5
Maintence Labor	31.8	
Maintence Materials	6.9	39.2
Electricity	37.7	
Waste Disposal	▨	
Solids 1280 lb/hr	30.3	
Sludge - lb/hr with - % solids content	-	
Total direct Operating Costs (TDOC)	▨	167.2
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	18.2	
Plant Overhead (26 percent of total labor + maintence materials	25.8	
Total Indirect Operating Costs (TIOC)	-	44.0
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	67.8	
Interest on Working Capital (10 percent)	4.2	
Capital Recovery (____ year equipment life, ____ percent interest)	223.0	
Total Capital Charges	▨	295.0
Total Annualized Costs	▨	506.2

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Date ___ ___	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr) ___	MSW / 400
Emission Control System / Emission Rate (lb/10^6 Btu)	ESP / 0.10

Comments : ______________________________

Capital Costs (10^3 \$)

Direct Investment Costs	Equip	Install		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP	490.5	490.5		
Scrubber				
- scrubber			–	
- scrubber auxiliaries				
EGB				
Fan and Motor	53.1	62.7		
Solids Separation				
Ducting	62.1	99.4		
Ash Removal	1.7	1.7		
Sand Classification				
Subtotal	607.4	654.3	1261.7	
Utilities and Services			75.7	
Total Direct Investment Costs (TDI)				1337.4
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			428.0	
Performance tests (greater of 1% of TDI or \$ 3000)			13.4	
Total Indirect Investment Costs (TII)			-	441.4
Total Direct and Indirect Investment Costs (TDI + TII)				1778.8
Total Turnkey Costs (TTC = TDI + TII + Contingencies [30% of TDI + TII])				2134.6
Land (0.00084 TTC)				1.8
Working Capital (25 percent of Total Direct Operating Costs)				44.5
Total Capital Costs (TTC + Land + Working Capital)				2180.9

Annualized Costs (10^3 \$)

Direct Operating Costs		Subtotals
Direct Labor	52.6	
Supervision	7.9	60.5
Maintenance Labor	31.8	
Maintenance Materials	8.9	101.2
Electricity	45.8	
Waste Disposal		
Solids 1308 lb/hr	30.9	
Sludge — lb/hr with — % solids content	-	
Total direct Operating Costs (TDOC)		177.9
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	18.2	
Plant Overhead (26 percent of total labor + maintenance materials	26.3	
Total Indirect Operating Costs (TIOC)	-	44.5
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	87.2	
Interest on Working Capital (10 percent)	4.4	
Capital Recovery (_____ year equipment life, _____ percent interest)	286.8	
Total Capital Charges		378.4
Total Annualized Costs		600.8

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	MSW / 400
Emission Control System / Emission Rate (lb/10^6 Btu)	ESP / 0.05

Comments: ____________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip	Install		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP	726.2	726.2		
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	53.1	62.7		
Solids Separation				
Ducting	62.1	99.4		
Ash Removal	1.7	1.7		
Sand Classification				
Subtotal	843.1	890.0	1733.1	
Utilities and Services			104.0	
Total Direct Investment Costs (TDI)				1837.1
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			587.9	
Performance tests (greater of 1% of TDI or $3000)			18.4	
Total Indirect Investment Costs (TII)			-	606.3
Total Direct and Indirect Investment Costs (TDI + TII)				2443.4
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				2932.1
Land (0.00084 TTC)				2.5
Working Capital (25 percent of Total Direct Operating Costs)				49.7
Total Capital Costs (TTC + Land + Working Capital)				2984.3

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	52.6	
Supervision	7.9	60.5
Maintenance Labor	31.8	
Maintenance Materials	12.2	104.5
Electricity	62.8	
Waste Disposal		
Solids 1328 lb/hr	31.4	
Sludge - lb/hr with - % solids content	-	
Total direct Operating Costs (TDOC)		198.7
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	18.2	
Plant Overhead (26 percent of total labor + maintenance materials	27.2	
Total Indirect Operating Costs (TIOC)	-	45.4
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	119.4	
Interest on Working Capital (10 percent)	5.0	
Capital Recovery (15 year equipment life, 10 percent interest)	392.4	
Total Capital Charges		516.8
Total Annualized Costs		760.9

Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Bagasse / 200
Emission Control System / Emission Rate (lb/10^6 Btu)	MC / 0.62

Comments: ______

Capital Costs (10^3 $)

Direct Investment Costs	Equip	Install		
	39.8	30.6		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	39.2	46.3		
Solids Separation				
Ducting	11.7	18.7		
Ash Removal	20.9	20.9		
Sand Classification	-	-		
Subtotal	111.6	116.5	228.1	
Utilities and Services			13.7	
Total Direct Investment Costs (TDI)				241.8
Indirect Investment Costs -				
Engineering & (10% of TDI) + Construction and Field Expense (22% of TDI)			77.4	
Performance tests (greater of 1% of TDI or $ 3000)			3.0	
Total Indirect investment Costs (TII)			-	80.4
Total Direct and Indirect Investment Costs (TDI + TII)				322.2
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI+TII])				386.6
Land (0.00084 TTC)				0.3
Working Capital (25 percent of Total Direct Operating Costs)				11.6
Total Capital Costs (TTC + Land + Working Capital)				398.5

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	7.8	
Supervision	1.2	9.0
Maintenance Labor	4.8	
Maintenance Materials	1.4	15.2
Electricity	13.8	
Waste Disposal		
Solids 886 lb/hr	17.5	
Sludge ______ lb/hr with ______ % solids content	-	
Total direct Operating Costs (TDOC)		46.5
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	2.7	
Plant Overhead (26 percent of total labor + maintenance materials	4.0	
Total Indirect Operating Costs (TIOC)	-	6.7
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	15.9	
Interest on Working Capital (10 percent)	1.2	
Capital Recovery (____ year equipment life, ____ percent interest)	52.4	
Total Capital Charges		69.5
Total Annualized Costs		122.7

Date	3-31-82
Fuel Type / Boiler capacity (10^6 Btu/hr)	Bagasse / 200
Emission Control System / Emission Rate (lb/10^6 Btu)	WS / 0.30

6" ΔP WS

Comments: ______________________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip	Install		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	76.6	52.1		
- scrubber auxiliaries	31.3	27.9		
EGB				
Fan and Motor	39.5	46.6		
Solids Separation	-	5.0		
Ducting	10.6	17.0		
Ash Removal				
Sand Classification				
Subtotal	158.0	148.6	306.6	
Utilities and Services			18.4	
Total Direct Investment Costs (TDI)			▨	325.0
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			104.0	
Performance tests (greater of 1% of TDI or $ 3000)			3.2	
Total Indirect investment Costs (TII)			-	107.2
Total Direct and Indirect Investment Costs (TDI + TII)				432.2
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				518.6
Land (0.00084 TTC)				0.4
Working Capital (25 percent of Total Direct Operating Costs)				23.9
Total Capital Costs (TTC + Land + Working Capital)				542.9

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	15.7	
Supervision	2.4	18.1
Maintenance Labor	9.5	
Maintenance Materials	11.0	38.6
Electricity	19.7	
Waste Disposal	▨	
Solids 0 lb/hr	-	
Sludge 1900 lb/hr with 50 % solids content	37.4	
Total direct Operating Costs (TDOC)	▨	95.7
Indirect Operating Costs	▨	
Payroll Overhead (30 percent of direct labor + supervision)	5.4	
Plant Overhead (26 percent of total labor + maintenance materials	10.0	
Total Indirect Operating Costs (TIOC)	-	15.4
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	21.7	
Interest on working Capital (10 percent)	2.4	
Capital Recovery (15 year equipment life, 10 percent interest)	71.4	
Total Capital Charges	▨	95.5
Total Annualized Costs	▨	206.6

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Date	3-31-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	Bagasse /200
Emission Control System / Emission Rate (lb/10^6 Btu)	WS /0.20 10" ΔP WS

Comments: ______________________________

Capital Costs (10^3 $)

Direct Investment Costs	Equip	Instal		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP				
Scrubber				
- scrubber	76.6	52.1		
- scrubber auxiliaries	31.3	27.9		
EGB				
Fan and Motor	39.5	46.6		
Solids Separation	-	5.0		
Ducting	10.6	17.0		
Ash Removal				
Sand Classification				
Subtotal	158.0	148.6	306.6	
Utilities and Services			18.4	
Total Direct Investment Costs (TDI)				325.0
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			104.0	
Performance tests (greater of 1% of TDI or $ 3000)			3.2	
Total Indirect investment Costs (TII)			-	107.2
Total Direct and Indirect Investment Costs (TDI + TII)				432.2
Total Turnkey Costs (TTC = TDI + TII + Contingencies [20% of TDI + TII])				518.6
Land (0.00084 TTC)				0.4
Working Capital (25 percent of Total Direct Operating Costs)				26.4
Total Capital Costs (TTC + Land + Working Capital)				545.4

Annualized Costs (10^3 $)

Direct Operating Costs		Subtotals
Direct Labor	15.7	
Supervision	2.4	18.1
Maintenance Labor	9.5	
Maintenance Materials	11.0	38.6
Electricity	28.8	
Waste Disposal		
Solids - lb/hr	-	
Sludge 1940 lb/hr with 50 % solids content	38.2	
Total direct Operating Costs (TDOC)		105.6
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	5.4	
Plant Overhead (26 percent of total labor + maintenance materials	10.0	
Total Indirect Operating Costs (TIOC)	-	15.4
Capital Charges	-	
G&A, Taxes and Insurance (4 percent of TCC)	21.8	
Interest on Working Capital (10 percent)	2.6	
Capital Recovery (15 year equipment life, 10 percent interest)	71.7	
Total Capital Charges		96.1
Total Annualized Costs		217.1

Date	10-13-82
Fuel Type / Boiler Capacity (10^6 Btu/hr)	SLW / 150
Emission Control System / Emission Rate (lb/10^6 Btu)	MC/FF / 0.05

Comments: ____________________

Capital Costs (10^3 $)

	Equip	Install		
Direct Investment Costs	30.5	25.3		
Multiclone				
Baghouse				
- baghouse	273.4	213.2		
- filter bags	26.7	26.7		
ESP				
Scrubber				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	33.1	39.0		
Solids Separation				
Ducting	24.2	38.7		
Ash Removal	16.5	16.5		
Sand Classification	10.7	14.3		
Subtotal	415.1	373.7	788.8	
Utilities and Services			47.9	
Total Direct Investment Costs (TDI)				836.1
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			267.6	
Performance tests (greater of 1% of TDI or $ 3000)			8.4	
Total Indirect Investment Costs (TII)				276.0
Total Direct and Indirect Investment Costs (TDI + TII)				1112.1
Total Turnkey Cost [TTC = TDI + TII + Contingencies (20% of TDI + TII)]				1334.5
Land (0.00084 TTC)				1.1
Working Capital (25 percent of Total Direct Operating Costs)				32.7
Total Capital Costs (TCC) = (TTC + Land + Working Capital)				1368.3

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	32.3	79.4
Electricity	27.2	
Waste Disposal		
Solids 460 lb/hr	24.2	
Sludge — lb/hr with ____ % solids content	-	
Total Direct Operating Costs (TDOC)		130.8
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials	20.6	
Total Indirect Operating Costs (TIOC)		29.6
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	54.7	
Interest on Working Capital (10 percent)	3.3	
Capital Recovery (15 year equipment life, 10 percent interest)	179.9	
Total Capital Charges		237.9
Total Annualized Costs		398.3

Date	10-13-82
Fuel Type / Boiler Capacity (10^3 lb steam/hr)	[illegible]/150
Emission Control System / Emission Rate (lb/10^6 Btu)	MC/ESP/0.10

Comments: ______

Capital Costs (10^3 $)

Direct Investment Costs	Equip. 30.5	Install. 25.3		
Multiclone				
Baghouse				
- baghouse				
- filter bags				
ESP	264.0	264.0		
Scrubbing				
- scrubber				
- scrubber auxiliaries				
EGB				
Fan and Motor	13.6	16.0		
Solids Separation	-	-		
Ducting	39.4	53.4		
Ash Removal	16.3	16.3		
Sand Classification	10.7	14.3		
Subtotal	368.5	389.3	757.8	
Utilities and Services			45.5	
Total Direct Investment Costs (TDI)				803.3
Indirect Investment Costs -				
Engineering (10% of TDI) + Construction and Field Expense (22% of TDI)			257.1	
Performance tests (greater of 1% of TDI or $3000)			8.0	
Total Indirect Investment Costs (TII)			-	265.1
Total Direct and Indirect Investment Costs (TDI+TII)				1068.4
Total Turnkey Cost (TTC = TDI + TII + Contingencies [20% of TDI+TII])				1282.1
Land (0.00084 TTC)				1.1
Working Capital (25 percent of Total Direct Operating Costs)				24.9
Total Capital Costs (TCC) = (TTC + Land + Working Capital)				1308.1

Annualized Costs (10^3 $)

		Subtotals
Direct Operating Costs		
Direct Labor	26.0	
Supervision	3.9	29.9
Maintenance Labor	17.2	
Maintenance Materials	5.3	52.4
Electricity	23.3	
Waste Disposal		
Solids 453 lb/hr	23.8	
Sludge - lb/hr with - % solids content	0	
Total Direct Operating Costs (TDOC)		99.5
Indirect Operating Costs		
Payroll Overhead (30 percent of direct labor + supervision)	9.0	
Plant Overhead (26 percent of total labor + maintenance materials	13.6	
Total Indirect Operating Costs (TIOC)	-	22.6
Capital Charges		
G&A, Taxes and Insurance (4 percent of TCC)	52.3	
Interest on Working Capital (10 percent)	2.5	
Capital Recovery (15 year equipment life, 10 percent interest)	172.0	
Total Capital Charges		226.8
Total Annualized Costs		348.9

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APPENDIX B

ESCALATION FACTORS

Appendix B presents the escalation factors used to convert the costs presented in this report (mid 1978 dollars) to a more current year basis. These factors are based on the Chemical Engineering Plant cost index.[1] To convert to a later year basis, the costs in mid-1978 dollars are multiplied by the escalation factor.

Basis	Escalation Factor
mid-1979	1.09
mid-1980	1.19
mid-1981	1.37
mid-1982	1.44

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[1] Economic Indicators. Chemical Engineering. 85(21):7, September 25, 1978; 86(20):7, September 24, 1979; 87(21):7, October 20, 1980; 88(21):7, October 19, 1981; 89(9):7, August, 1981; 90( ):7.